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TEXTILE EDUCATION IN SOUTH KOREA

by

DR. CHAPIN A. HARRIS*

I. The Korean Textile Industry

The Republic of Korea has a rather large textile industry. The production is confined mainly to cotton fabrics such as bagging, sheeting, shirting, poplins, and some knit goods. Silk, rayon, and nylon fabrics are made in plain and fancy weaves. The production of woolens and worsteds is extremely small. Physically, this industry was seriously damaged during the Korean War. Another major difficulty has been the need for technicians, technical supervisors, and executive personnel. During the Japanese control from 1905 until August 15, 1945, such technical supervisory and administrative positions were held by them. Accordingly, there has been a real problem of rehabilitation and readjustment. The state of the mills alone makes it necessary to have technically trained men who have had practical laboratory practice as well as a thorough grounding in the theoretical backgrounds of engineering and chemistry, and in the techniques of a specific industry.

II. Technical Education

Technical education in specialized fields is generally designed as much as possible to meet the needs of the particular industry it serves. To be sure, the needs of the industry sometimes change more rapidly than the course contents do, but in the main the objective is reasonably well fulfilled.

Oriental education has always tended to lean heavily on the theoretical approach in teaching, because the learned man in earlier oriental culture avoided doing things with his hands. This is in direct opposition to the generally accepted views on higher technical training, in which the student develops into the learned man by applying theory to practical situations through well designed laboratory experiments. This background, coupled with the almost complete loss of any laboratory equipment existent before the Korean War, has created the real problem of trying to keep Korean technical education in pace with industry's need for men with a well rounded training.

As might be expected, the Japanese control of Korea, as well as the recent war, did little to help the supply of qualified college teachers or the availability of laboratory equipment. This was true of all Korean colleges, including Seoul National University which has the only Textile Engineering curriculum in South Korea.

*Dr. Chapin A. Harris is Director of the Graduate School and Head of the Department of Fibers and Yarns at Lowell Technological Institute, Lowell, Massachusetts. He spent nearly three months in the summer of 1956 in South Korea as Adviser in Textile Engineering to Seoul National University under the International Cooperation Administration—University of Minnesota contract for the rehabilitation of Seoul National University. Other advisers have been or will be sent to cover other areas of the university such as agriculture, medicine, and other engineering departments. The advisers have attempted to help in the development of curricula and general educational policy and particularly to aid in the preparation of equipment lists to cover laboratory needs in these schools and departments. After final approval by the University of Minnesota and ICA, the equipment will be purchased and sent to S.N.U. The program is advanced to the point where some equipment is actually being received at Seoul.

Many of the members of the engineering faculties in Korea recognize the situation. Some are rather impatient with it and are working desperately to change it, but several observers have pointed out that Korean faculty and students tend to endure the state of affairs rather impassively. It is, of course, very easy for a Westerner to criticize this condition without considering all the factors that have brought it about. The author believes that, although this typically oriental tolerance and passiveness do exist, there is arising sufficient restlessness, especially among the younger faculty members, to spearhead a general change in educational philosophies and methods from the traditional to more enlivened practical and aggressive concepts of teaching.

III. Textile Education

A. High-School Level

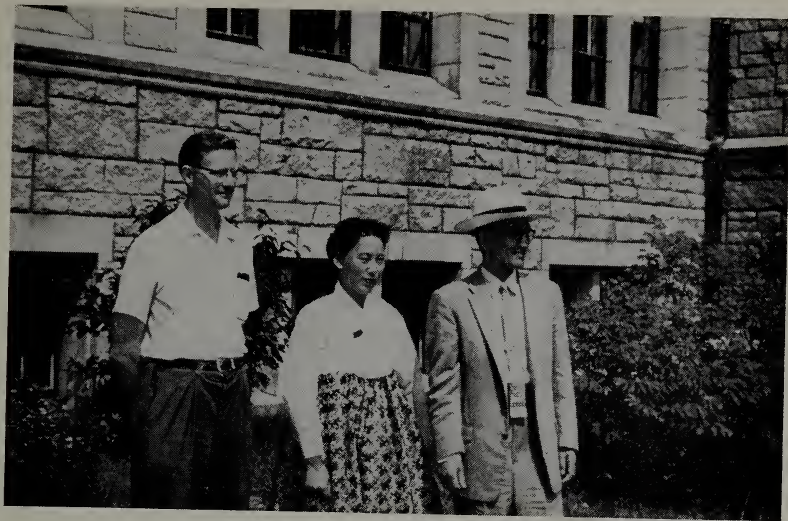
Textile education in Korea is available at the high-school level as well as at the university level (both undergraduate and graduate). There are ten technical high schools that offer courses in certain phases of textiles. These schools are scattered throughout the major industrial cities and try to serve the need for technicians in the various areas. Even at this level, though, textile education tends to be more theoretical than practical. However, there is no doubt that the graduates of these technical high schools are performing invaluable services to the industry.

The lack of equipment for training in the technical high schools is as acute as it is at the university. The office of the Economic Coordinator for Korea (OEC) under the International Cooperation Administration (ICA) is doing much to help these technical high schools to get laboratory equipment. The United Nations Korean Reconstruction Agency (UNKRA) started the work, and ICA is carrying on this rehabilitation. Some textile mills in the vicinity of some of these schools allow the use of their machines for practical training. With the present state of the textile industry and its need for skilled maintenance men, quality control assistants, and personnel with the ability to train unskilled workers, the technical high schools can play a very important role.

B. University Level

Seoul National University is the largest university in Korea. It was founded in 1913 by the Japanese as Keijo Imperial University and was attended mostly by them before 1945. The teaching staff was also Japanese. The University includes Colleges of Liberal Arts and Science, Engineering, Law, Commerce, Medicine, Dentistry, Education, Pharmacy, Agriculture, Music, Fine Arts, and Veterinary Medicine, and a graduate school. The College of Engineering is about ten miles northeast of Seoul, and the College of Agriculture is located in Suwon, thirty miles south. The rest of the University is rather centrally located in the city itself. Of the 12,000 students, 1800 are enrolled at the Engineering College. One hundred and sixty students are taking textile engineering, working toward the Bachelor of Science degree. Six graduate students were registered in Textile Engineering this past year, working toward the Master's degree.

The faculty of the Textile Engineering Department consists of five members, three professors and two instructors. Because of the low salary scale (about 1/3 that of comparable level in industry) the maximum teaching load is ten hours per week to allow for outside work of some



The author with Professor and Mrs. Bum Shik Woo. Prof. Woo is Head of the Textile Engineering Department and Dean of Students of the Engineering College at S.N.U. He spent the academic year 1955/56 at L.T.I.

The Heung Han Spinning Co. of Inchon was badly damaged during the Korean conflict. This picture shows a part that has not been rebuilt and is a good example of the condition of most of the textile mills north of Taegu in 1953.

sort to augment the salary. A Department Head has somewhat less of a teaching load because of administrative duties. Because of this situation, members of the faculty are seldom available outside their teaching hours. Many of them teach in other colleges or run businesses of their own. Because of the transportation problems, faculty attendance at classes has been somewhat spotty. The Dean of the College of Engineering has recently ruled that faculty attendance at regularly scheduled classes is required. This ruling has reduced faculty absenteeism at the Engineering College during the past year.

The Textile Engineering faculty teach only textile subjects. The basic chemistry and engineering subjects, as well as mathematics, physics, and the humanities, are supplied by other departments and colleges.

Some of the staff in this department (as well as throughout the University) have been to, are in, or will be sent to this country for advanced training. Professor Bum Shik Woo, Head of the Textile Engineering Department and Dean of Students of the College of Engineering, spent the 1955/1956 academic year at Lowell Technological Institute as a special graduate student, studying our methods of teaching design and weaving. Mr. No Su Kim, an instructor, was here at the same time, working in the field of textile chemistry. Mr. Jae Lin Woo is now at Massachusetts Institute of Technology, but is also commuting to Lowell to take some subjects under the M.I.T.-L.T.I. cooperative plan. One of the major purposes of having Seoul National University faculty members study in this country is to acquaint them with our laboratory methods of teaching and to bring them up to date on the latest developments in the field. This training and experience will prepare them to make the best use of the laboratory equipment which the advisers are recommending that the ICA purchase for the University within the budget of the University of Minnesota contract for the rehabilitation of S.N.U. The temporary absence of these men has brought about some very real administrative and teaching problems which have, unfortunately, put an extra burden on the present students.

Although the Textile Engineering Department of S.N.U. is one of the best equipped in the Engineering College, the inadequacy is quite startling to anyone used to the abundance of our laboratory facilities. There are a slightly damaged cotton card, a drawing frame, a roving frame, a spinner, a small loom (under construction), two inoperable knitting machines, and two low-capacity tensile testers. The dyeing laboratory has some benches, a few beakers and other glass ware, and inadequate heating facilities. Practically no laboratories or classrooms have lights. This prevents classes before 9 o'clock in the morning or after 4 o'clock in the afternoon. The lack of sufficient fuel to heat the University presents serious difficulties with respect to efficient teaching in the winter. Overcoats are frequently needed in classrooms during the cold weather.

This background of history and culture, the conflict of adjustment to freedom and a new world, the status of the faculty, and the physical condition of the buildings and lack of equipment very naturally have had a great influence on the development and execution of the present curriculum.

The four-year course as given in the most recent catalogue is as follows:

The Cheil Woolen Textile Co. in Taegu is probably the most modern textile mill in Korea. Devoted to the manufacture of worsted yarns and fabrics, it is completely air-conditioned and equipped with the very latest machinery.

The main building of the College of Engineering overlooks the ruins of the Mining Engineering Department in the foreground. This section of Seoul National University was used by both the U.N. and Communist forces several times during the war, and, therefore, was subject to heavy bombardment.

FRESHMAN YEAR

(Common to all engineering curricula)

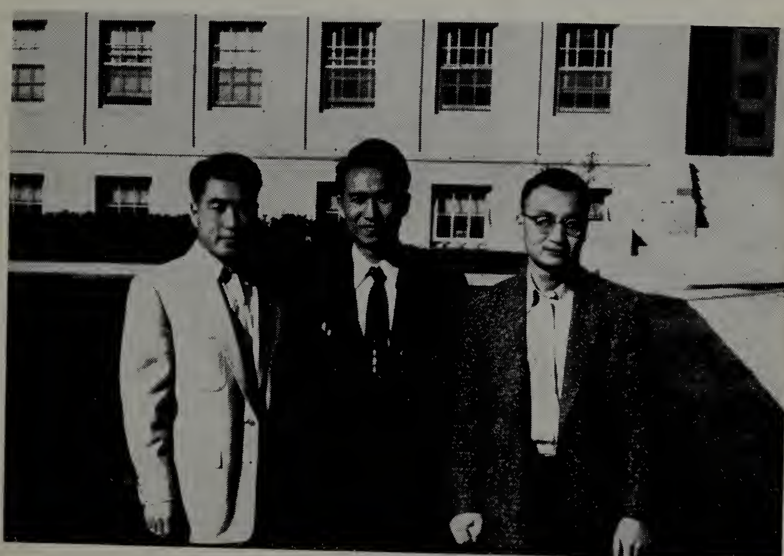
Subject	First Semester Hr/Wk	First Semester Credits	Second Semester Hr/Wk	Second Semester Credits
Korean	2	2	2	2
English	4	4	4	4
German	2	2	2	2
Introduction to Philosophy	2	2	—	—
Outline of History	—	—	2	2
Algebra and Geometry	4	2	4	2
Differential and Integral Calculus	4	2	4	2
Physics	4	2	4	2
Physics Laboratory	2	1	2	1
General Chemistry	2	2	2	2
Chemistry Laboratory	3	1	3	1
Descriptive Geometry	1	1	1	1
Gymnastics	2	1	2	1
Total	32	22	32	22

All subjects are required in Freshman course.

SOPHOMORE YEAR

Subject	First Semester Hr/Wk	First Semester Credits	Second Semester Hr/Wk	Second Semester Credits
Required Subjects				
Gymnastics	1	1	1	1
Korean	1	1	1	1
Social Science	2	2	2	2
Applied Physics	2	2	2	2
Engineering Drawing	2	1	2	1
Engineering Mechanics	2	2	2	2
Differential Equations	2	2	2	2
Strength of Materials	2	2	2	2
Kinematics of Machinery	2	2	2	2
Qualitative Analysis	6	2	—	—
Theory of Functions	2	2	2	2
Metallic Materials	2	2	2	2
Organic Chemistry	3	2	3	2
Quantitative Analysis	—	—	6	2
Mechanical Engineering	2	2	2	2
Total	31	25	31	25
Elective Subjects				
English or German	2	2	2	2
Total	2	2	2	2

The Textile Engineering Building was not badly damaged but has little equipment and is now being used mainly as a dormitory.



Mr. Dae Yee Kim, Mr. No Su Kim, and Mr. Tchang Il Chung at Lowell Technological Institute, where Mr. D. Y. Kim is a special student in Textile Engineering. Mr. N. S. Kim is a member of the S.N.U. faculty who studied Textile Chemistry at L.T.I., and Mr. Chung is working for his M.S. degree in Textile Engineering at Lowell.

JUNIOR YEAR

Subject	First Semester Hr/Wk	First Semester Credits	Second Semester Hr/Wk	Second Semester Credits
Required Subjects				
Electrical Engineering	2	2	2	2
Textile Fibers	2	2	2	2
Spinning I	3	3	3	3
Mechanism of Weaving I	2	2	—	—
Mechanism of Weaving II	—	—	2	2
Textile Mechanism	3	3	—	—
Textile Testing	—	—	3	3
Textile Scouring and Bleaching	2	2	—	—
Knitting Technology I	2	2	2	2
Dyeing	2	2	2	2
Textile Design I	2	2	2	2
Total	20	20	20	20
Elective Subjects				
Electrical Engineering Laboratory	—	—	2	1
Thermodynamics I	2	2	2	2
Thermodynamics II	2	2	2	2
Man-made Fibers	2	2	2	2
Textile Pattern Design	2	2	—	—
Textile Finishing	—	—	3	3
Chemistry of Dyestuffs	—	—	2	2
Physical Chemistry	2	2	2	2
English	1	1	1	1
Textile Engineering Laboratory I	7	3	7	3
Total	14	14	21	17

SENIOR YEAR

Subject	First Semester Hr/Wk	First Semester Credits	Second Semester Hr/Wk	Second Semester Credits
Required Subjects				
Knitting Technology II	3	3	—	—
Mechanism of Weaving	2	2	—	—
Dyeing II	—	—	3	3
Fabric Design and Analysis	2	2	—	—
Total	7	7	3	3
Elective Subjects				
Industrial Economics	2	2	—	—
Sociology	—	—	2	2
Politics	2	2	—	—
Shop Building	—	—	2	2
Spinning II	3	3	—	—
Jacquard Design and Weaving	—	—	3	3
Machine Design	3	3	—	—
Spinning III	—	—	3	3
Spinning IV	—	—	3	3
Theory of Spinning	3	3	—	—
Mechanics of Looms	—	—	3	3
Textile Quality Control	3	3	—	—
Textile Cost Accounting	—	—	2	2
Mill Planning	2	2	—	—
Factory Equipment and Code	—	—	2	2
Synthetic Fibers	2	2	—	—
Chemical Engineering	—	—	2	2
Textile Engineering Laboratory II	9	4	9	4
Textile Design II	2	2	2	2
Total	26	21	34	29

There are several outstanding features of this curriculum. Some of these are difficult to assess because of the basic differences between oriental and western education. The first point of interest is the rather heavy credit-hour load. As in this country, one credit hour normally indicates three hours of work. Two hours of preparation are supposed to go along with one hour of lecture or recitation. Two or three hours of laboratory are generally given a one credit-hour rating. In our country a credit-hour load of 20 per semester is considered sufficient, and many colleges have a lower load for the freshman year.

However, the credit hours given are not quite as bad as it might seem for three reasons. Very little homework is assigned because staff members do not have time for correcting it. Some of the lecturing is

of the "textbook" type. That is, the lecturer either reads the textbook or follows it so closely that there is little stimulation to go beyond the text. The library facilities are rather meager.

Another noticeable thing about the curriculum is the large number of different subjects the students must take. Considering the laboratories as part of the subjects listed as lectures, and excluding gymnastics, there are nine different subjects required in the freshman year. This is at least two more, but usually about four more, subjects than are required of freshmen in engineering curricula in this country.

The requirement of two foreign languages, both English and German, in the freshman year indicates the conflict that must exist because of the change in world conditions. German has been considered as an essential language to the scientist and engineer. With the present-day position of America in world affairs and particularly in scientific fields, and also with respect to its Korean relief program, the Koreans are anxious to know English. The outcome has put a rather heavy burden on college students.

Although the junior and senior years are arranged so that textile engineering students may elect certain subjects, the curriculum comes close to attempting to educate a textile engineer and a textile chemist with one program. This is one other reason for the very heavy schedule.

During the period in which some of the S.N.U. faculty members are in this country for study, it has been impossible to offer all the subjects listed. Therefore, the students have not been able to make up programs of their own choice.

The lack of laboratory equipment has been a major drawback. It is difficult to see how such subjects as applied physics, electrical engineering, textile testing, and various other subjects can be adequately covered without some laboratory work. The faculty is concerned; but the students develop a feeling of frustration at not being able to grapple physically with the problems covered in principle and theory only. Some students are able to find summer work in textile mills which gives them some practical training. This situation should be relieved to a great extent within the next two or three years through the present ICA Minnesota program.

IV. Textile Engineering Graduates

With about forty textile engineers being graduated per year in the last two years or so, it is interesting to note what happens to them and also what need for them exists. About 90 percent of these graduates (as is the case with most S.N.U. engineering graduates) must report immediately for duty in the ROK army for a two-year period. Only ten percent, then, can go directly into the textile industry. This is in some respects fortunate, because although the industry is in dire need of trained engineers, it finds itself unable to absorb all these men as rapidly as they are graduated. As the general financial situation in Korea improves so that consumer buying power increases, mills will be more able to turn their attention to quality control programs and improvement in equipment and facilities; thus they should not only need, but be able to utilize, the skilled engineers.

In visits to numerous textile mills throughout South Korea, the writer saw the need for trained men and also met and talked with former S.N.U. Textile Engineering graduates who were working hard to rehabilitate war-damaged plants, to meet production quotas, to keep ancient machinery

operating, to adjust to shortages of raw material without losing trained help, to keep quality as high as possible and even to think a little of the future. It was quite evident that these recent graduates had had a sound educational background, were very well informed of recent developments, and were very anxious to aid in the industrial development of their country.

There is, as might be expected, a great desire for further training by S.N.U. graduates. Because of the lack of equipment, most of these people want to study in America. Very few can come—financial difficulties, school quotas, the need for sponsors, and the army service requirements limit the number. There are two Korean students studying Textile Chemistry in the Graduate School at L.T.I. this year. There is one student who has been accepted for next year and several more whose applications are pending. There are several Koreans studying textiles in the undergraduate school.

V. Conclusion

As is the case with many phases of life in Korea, the textile industry and textile education are beset with many difficult problems. However, many of these will soon be overcome, thanks to the spirit of the Koreans—particularly the young people—and the financial aid being supplied by other parts of the free world. In watching the growth and changes that are taking place and will take place, the western observer should be careful in criticizing because there are many features of oriental culture and education that are worthy of consideration. Furthermore, it is probably not the best thing for the Koreans to copy our ways entirely, but rather to develop their own system based on what they see as useful in our methods combined with the better characteristics of their culture.

Their progress toward rehabilitation and improvement of conditions in the face of heavy odds and an uncertain future is worthy of commendation by all the world.

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LOWELL TECHNOLOGICAL INSTITUTE

Lowell, Mass.

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1957-1958

Aerial View of Campus

Alumni Memorial Library

SERIES 60, NO. 4 May, 1957

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The Institute reserves the right to make changes in the regulations, courses, and charges announced in this Bulletin.

INSTITUTE CALENDAR
FOR
ACADEMIC YEAR 1957-1958

1957

September 9, Monday, 9 A.M.	Freshman Orientation Week begins.
	Registration of graduate students begins.
September 12, Thursday, 9 A.M.	Registration of upperclassmen begins.
September 13, Friday, 4 P.M.	Registration of all classes ends.
September 16, Monday, 8 A.M.	Undergraduate classes begin.
September 17, Tuesday, 8 A.M.	Graduate classes begin.
September 27, Friday	Last day to register for new classes.
October 11, Friday	Last day to drop classes without penalty.
November 11, Monday	Veterans' Day. Institute closed.
November 27, Wednesday, 12 Noon	Thanksgiving recess begins.
December 2, Monday, 8 A.M.	Classes resume.
December 20, Friday, 12 Noon	Christmas recess begins.

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January 6, Monday, 8 A.M.	Classes resume.
January 13, Monday	Registration for second semester begins.
	Classes continue.
January 20, Monday, 8 A.M.	First-semester examinations begin.
January 29, Wednesday, 5 P.M.	First-semester examinations end.
January 31, Friday	Registration for second semester ends.
February 3, Monday, 8 A.M.	All classes begin.
February 14, Friday	Last day to register for new classes.
February 28, Friday	Last day to drop classes without penalty.
March 28, Friday, 5 P.M.	Easter recess begins.
April 7, Monday, 8 A.M.	Classes resume.
May 26, Monday, 8 A.M.	Second-semester examinations begin.
May 30, Friday	Memorial Day. Institute closed.
June 6, Friday, 5 P.M.	Second-semester examinations end.
June 15, Sunday	Baccalaureate and Commencement.

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Harry C. Brown, B.S., *Professor, in charge of Department*
Herbert J. Ball, S.B., B.C.S., Sc.D., *Fellow of the Textile Institute (British), Professor Emeritus*
Walter J. Hamburger, S.B., S.M., Ph.D., *Visiting Professor*
Maurice E. Gelinas, S.B., A.M., *Professor*
Melvin Mark, B.M.E., M.S., Sc.D., *Professor*
Henry E. Thomas, B.T.E., *Professor*
A. Edwin Wells, B.T.E., M.Ed., *Professor*
Horton Brown, B.S., *Associate Professor*
J. Arthur Ainsworth, B.S., M.S., *Assistant Professor*
Elliot F. Humiston, Jr., S.B., *Assistant Professor*
Kenneth L. Rogers, B.S., *Assistant Professor*
Frederick B. Bischoff, B.S., M.S., *Instructor*
Bernard C. Harcourt, B.S., M.A., *Instructor*
F. Raymond Hardy, B.S., *Instructor*
James A. Irvine, B.T.E., *Instructor*

Division of General Studies

John R. Robertson, A.B., A.M., *Professor, Chairman of Division, and in charge of Department of Social Sciences*

Department of Air Science

Lt. Col. Harry E. Stengele, B.S., *Professor, in charge of Department*
Capt. Frank B. Amado, A.A., *Assistant Professor*
Capt. Kenneth J. Cahill, B.A., *Assistant Professor*
1st. Lt. John P. Chervenak, B.S., *Assistant Professor*
1st Lt. Thomas E. Convery, B.S., M.Ed., *Assistant Professor*
M/Sgt. Joseph W. Adamski, *Instructor*
M/Sgt. David H. Mace, *Instructor*
S/Sgt. Lucien E. Fecteau, *Instructor*
S/Sgt. Norman C. Lombardi, *Instructor*
S/Sgt. Lawrence D. Wallace, *Instructor*

Department of Languages and Humanities

Lester H. Cushing, A.B., Ed.M., *Professor, in charge of Department*
James G. Dow, A.B., *Professor*
Wentworth Williams, B.A., Ed.D., *Professor*

John J. MacLaughlan, Ph.B., A.M., *Associate Professor*
Howard K. Moore, A.B., A.M., Ph.D., *Assistant Professor*
David B. Morey, B.S., M.A., *Assistant Professor*
Waldo W. Yarnall, B.S., *Assistant Professor*
Thomas Higgins, B.A., M.A., *Instructor*
Charles E. Jarvis, B.S., M.A., *Instructor*
Joseph Rogers, B.A., M.A., B.D., *Instructor*

Department of Physical Education

Lester H. Cushing, A.B., Ed.M., *Professor, Director of Athletics*
David B. Morey, B.S., M.A., *Assistant Professor and Coach*
Waldo W. Yarnall, B.S., *Assistant Professor and Coach*

Department of Social Sciences

John R. Robertson, A.B., A.M., *Professor, in charge of Department*
Stuart L. Mandell, A.B., M.B.A., *Associate Professor*
John R. Sanders, A.B., M.B.A., *Instructor*
George J. Toscano, B.S., *Instructor*

Division of Textiles

Jacob K. Frederick, Jr., B.S., *Professor, Chairman of Division, and in charge of Department of Evaluation*

Department of Fibers and Yarns

Chapin A. Harris, B.S., Ph.D., *Professor, in charge of Department*
James H. Kennedy, Jr., B.T.E., M.S., *Professor Emeritus*
Gilbert R. Merrill, B.T.E., *Professor Emeritus*
Jacob K. Frederick, Jr., B.S., *Professor*
Russell L. Brown, B.S., *Associate Professor*
John A. Goodwin, B.T.E., M.S., *Associate Professor*
Clarence J. Pope, B.S., M.S., *Associate Professor*
J. Frederic Burtt, B.T.E., *Assistant Professor*
Fritz F. Kobayashi, *Assistant Professor*
David H. Pfister, B.S., M.S., *Assistant Professor*
Kenneth S. Merrill, B.S., *Instructor*

Department of Fabrics

Vittoria Rosatto, B.S., *Professor, in charge of Department*
Hermann H. Bachmann, *Professor Emeritus*
Russell M. Fox, *Professor Emeritus*
Martin J. Hoellrich, *Professor Emeritus*
Edward L. Golec, B.S., *Associate Professor*
Nathaniel E. Jones, *Associate Professor*
John L. Merrill, B.T.E., *Associate Professor*
George G. Armstrong, Jr., *Assistant Professor*
Robert C. Gray, *Assistant Professor*
Albert T. Woidzik, B.S., *Assistant Professor*

Department of Finishing

John J. McDonald, B.T.C., M.S., *Professor, in charge of Department*
C. Leonard Glen, *Professor Emeritus*
Winford S. Nowell, B.M.E., *Associate Professor*
Robert E. Morrison, B.S., *Instructor*

Department of Evaluation

Jacob K. Frederick, Jr., B.S., *Professor, in charge of Department*
David H. Pfister, B.S., M.S., *Assistant Professor*

Other Officers and Assistants

Health Services

Arlene D. Gordon, R.N.	*Resident Nurse*
(Local physicians and specialists as required)	

Library

Ruth A. Fitzgerald	*Library Assistant*
Robert L. Deignan	*Library Assistant*
Lorraine A. Richer	*Library Assistant*
Sue Goodsoozian	*Library Assistant*

Administrative Assistants

Helen G. Flack, S.B.	*Executive Secretary*
Theresa D. LeBlanc	*Office of the Dean of Faculty*
Elizabeth P. Kennedy	*Office of the President*
Mona M. Davis	*Division of Chemistry*
Kleonike Bentas	*Office of the Assistant to the President*
Eleanor M. McKenna	*Division of Engineering*
Doris D. Couture	*Division of General Studies*
Rene Curley	*Office of Admissions*
Doris F. Gagnon	*Office of Special Services*
E. Joyce Larkin	*Division of Engineering*
Barbara J. Maccaron	*Office of the Dean of Students*
Pauline D. McKenna	*Division of Textiles*
Maureen S. Naze	*Receptionist*
Barbara M. Jaros	*Office of the Bursar*
Joseph H. Lecam	*Office of the Bursar*
Catherine P. Ouollette	*Office of the Bursar*
John L. Sayer	*Office of the Bursar*
Joyce A. Sullivan	*Office of the Bursar*
Terese M. Brunelle	*Office of the Registrar*
Lorraine I. LeDoux	*Office of the Registrar*
Nora M. MacBrayne	*Office of the Registrar*

Buildings and Power

Charles A. Henry	*Chief Engineer*
Joseph A. Nerney	*Superintendent of Buildings*

ALUMNI ASSOCIATION

Objects of the Alumni Association are to advance the interests of Lowell Technological Institute, to secure systematic and unlimited gifts thereto and to receive and hold money and property, both real and personal, and to manage, use, and dispose of the same as appears to be in the best interests of the Institute.

All students of the Institute who have completed satisfactorily at least one year of the day curriculum are eligible for active membership. Only the active members have the right to vote and hold office in the Association.

The by-laws of the Association also provide for Honorary and Associate memberships. The Honorary Membership Scroll and Citation may be awarded by the Board of Directors to any person who has made outstanding contribution to the arts or sciences. Any person not otherwise eligible for membership who has made significant contribution to the welfare of the Institute may be elected to Associate membership by the Board of Directors. The Honorary Award Scroll and Citation may be awarded by the Board of Directors to any active member of the Alumni Association who has made outstanding contribution to the arts or sciences.

The Association administers numerous scholarships and fellowships; publishes the magazine, "The L.T.I. Alumni Bulletin," three times annually; publishes an Alumni Directory; aids student organizations; and performs the functions usually associated with alumni organizations. Membership is held in the American Alumni Council.

The Association holds its annual business meeting and banquet in the spring of each year.

Communications should be addressed to Professor A. Edwin Wells, Executive Secretary, Alumni Office, Lowell Technological Institute.

Officers for the Year 1956-1957

Bryan Leonard, '18, *President*
Clifford A. Harvey, '49, *First Vice President*
Eugene F. Crane, '33, *Second Vice President*
A. Edwin Wells, '20, *Clerk, Treasurer and Executive Secretary*
Ernest P. James, '42, *Assistant Secretary*

Alumni Fund Council

Levon M. Yacubian, '26, *Chairman*
Evan H. Fairbanks, '35, *Vice Chairman*

RESEARCH FOUNDATION

In recognition of the unique research opportunities afforded to industry by virtue of the equipment and staff available at Lowell Technological Institute, the Massachusetts State Legislature, in November, 1950, authorized the establishment of the Lowell Technological Institute Research Foundation. Its purpose is to conduct research, development, and consulting programs under contract with responsible agencies and industrial organizations. This activity has the effect of permitting staff members access to new and significant developments in industry and materially assists in keeping the teaching programs current and dynamic.

The Research Foundation provides the necessary mechanism whereby all of the research work of the Institute is brought under one coordinating office headed by the Executive Director. As in the past, however, the faculty of the Institute does the greater part of the research work. This plan has been proved through years of experience to be highly beneficial to both the Institute and industry.

The Foundation has the use of the Institute's laboratory and research facilities in chemistry, physics, engineering, textiles, electronics, paper, leather and plastics. The Institute has many unusual research facilities. These include a completely equipped laboratory for work with radio-active materials, an Instron tester, x-ray diffraction equipment, a large spectrograph, recording spectrophotometers, a pulse-propagation meter, and a completely equipped laboratory for microscopic work including phase microscopy and electron microscopy.

It is probably the only research organization in the world having at its disposal fully equipped laboratories to manufacture and finish nearly all types of fibers by all the common manufacturing systems as well as similar equipment for paper, leather and plastics processing. These splendidly equipped laboratories serve as pilot plants for the evaluation of industrial and manufacturing problems submitted to the Foundation.

The Foundation organization is built around the three basic divisions of Research, Development, and Testing, and is currently active in all three fields for both governmental agencies and industrial organizations.

For further information and descriptive literature about the Research Foundation, write to Mr. Dorrance H. Goodwin, Executive Director, Lowell Technological Institute Research Foundation, 1 Textile Avenue, Lowell, Mass.

Lowell Technological Institute

GENERAL INFORMATION

History

Lowell Technological Institute was incorporated in 1895 and formally opened for the teaching of textile manufacturing subjects on January 30, 1897. It was then known as the Lowell Textile School and awarded only certificates and diplomas. Growth of the school in size, prestige, and scope of curricula was rapid, and in 1913 it was granted the right to give regular four-year degrees in textile engineering and textile chemistry.

In 1928 the name was changed to the Lowell Textile Institute to indicate more fully its collegiate status. Its continued growth resulted in further diversification of its areas of specialization and in 1950 it entered the fields of paper engineering and leather engineering. Electronic engineering was added in 1953 and plastics engineering in 1954. A course in general engineering was introduced in 1956, and in September of 1957 a course in chemistry will be added.

In view of the present greatly expanded scope of its engineering program, its name was once more changed in 1953 to the Lowell Technological Institute. The Institute grants Bachelor of Science and Master of Science degrees and is authorized to set up a program leading to the doctorate.

Since 1918, when the property of the school was transferred to the Commonwealth of Massachusetts, it has been under the control and management of a Board of Trustees appointed by the Governor.

Accreditation

The Institute is a full member in the Senior College Division of the New England Association of Colleges and Secondary Schools. The United States Department of Education and the Armed Forces consider such membership equivalent to regional accreditation. The Engineers' Council for Professional Development extends full accreditation to the curricula in textile engineering.

Graduates of this Institute have been accepted for graduate study at nearly all leading universities. The Institute's prestige in its early field of specialization, textiles, has attracted students annually to L.T.I. from approximately 35 other countries.

Coeducation

The Institute accepts both men and women for entrance provided they are properly qualified graduates of an accredited secondary school. While the great majority of its students are men, the Institute has attracted for some years a small but significant group of young women who recognize the increasing opportunities open to technically trained women in industry.

Location

Lowell Technological Institute is located in Lowell, Mass., a city of 100,000, long famous as a textile center and more recently as a city of increasingly diversified industries. The campus is composed of ten main buildings located on a 15-acre site along the west bank of the Merrimack River and overlooking the rapids of Pawtucket Falls. The campus site was donated by Frederick Fanning Ayer, Esquire, and the Proprietors of the Locks and Canals on the Merrimack River.

Buildings

Southwick Hall. This was the first building erected on the present campus and was dedicated in 1903 as the gift of the Commonwealth of Massachusetts and Frederick Fanning Ayer. It is a memorial to Royal Southwick, an ancestor of Mr. Ayer and a leading textile manufacturer and public figure of his day. It contains the gymnasium, student mail room, administrative offices of the four faculty divisions and the AFROTC detachment, and the national headquarters of the American Association of Textile Chemists and Colorists.

Kitson Hall. Completed in 1903, Kitson Hall was erected by Charlotte P. Kitson and Emma K. Stott as a memorial to their father, Richard Kitson, founder of the Kitson Machine Company of Lowell. It contains classrooms and laboratories.

Falmouth Street Building. Erected in 1903 as a one-story building, it was enlarged to its present capacity for classroom and laboratory facilities in 1907 by the Commonwealth of Massachusetts.

Louis Pasteur Hall. Originally constructed as a one-story building, it was enlarged to four stories in 1937 by the Commonwealth of Massachusetts and houses laboratories and classrooms as well as the national research laboratories of the American Association of Textile Chemists and Colorists.

Olney Hall. Completed in 1952 by the Commonwealth of Massachusetts, this modern building houses complete leather and

paper manufacturing facilities, advanced textile testing and electronic laboratories, as well as many modern lecture rooms.

Alumni Memorial Library. Erected in 1951 by the Alumni Association through contributions from alumni and friends of the Institute, the modern library is dedicated to the men and women of the Institute who served this nation in World Wars I and II and the Korean conflict.

Besides a book stack capacity of 80,000 volumes, it contains student activity offices, alumni offices, reading rooms, typing facilities, micro-film room and faculty studies. It houses one of the most complete collections of textile books in the world and numerous special collections in the fields of paper, leather, chemistry, electronics, and plastics. It also serves as a depository for U. S. Government publications and is available to industrial concerns through its Industrial Corporate Membership program.

Cumnock Hall. Completed in 1954, this auditorium-administration building provides a 1200-seat auditorium for academic convocations and social activities. It also contains the offices of the President and Assistant to the President, the Dean of Faculty and the Dean of Students, Graduate School, Admissions, Special Services, Placement, the Bursar, the Registrar, and the L.T.I. Research Foundation.

Smith Hall. Erected in 1948 by the Lowell Textile Institute Building Association, Smith Hall has living accommodations for 112 students. The basement contains the college cafeteria and a medical dispensary. It was dedicated in honor of James T. Smith, pioneer educator in the textile field and the individual primarily responsible for the organization of the Lowell Textile School in 1895.

Eames Hall. The second men's residence hall was completed in 1949 by the Lowell Textile Institute Building Association and contains living quarters for 112 students, a student lounge and recreation center, and a snack bar. It was dedicated in honor of Charles H. Eames, President of the Institute from 1905 to 1945.

Equipment

The total value of the scientific and industrial equipment used in the instructional and research program of the Institute is approximately seven million dollars. This equipment ranges from the most delicate scientific instruments, such as the electron microscope, to full-sized industrial machines.

The textile manufacturing equipment includes a full line of machines for processing any fiber, whether natural or man-made,

on the cotton, woolen, French worsted, English worsted or American worsted systems. It also includes a modern throwing plant for filament yarns and a garnetting unit to reclaim used fibers.

All types of modern looms and knitting machines together with a full line of wet and dry finishing equipment enable the Institute to manufacture, under almost all industrial conditions, any type of fabric and finish desired.

The textile testing laboratories are among the most completely equipped in the world and have the use of the extensive optical and electronics facilities used in advanced research work.

In the completely equipped paper and leather laboratories both leather and paper of nearly all grades and types can be fully processed from raw materials, finished, and tested by the most modern methods, and an ambitious program of replacement of machinery is under way which will make the Institute eventually the finest equipped and most completely modernized of any in the country.

The wide variety of electronic and plastics equipment already available is in the process of being greatly augmented and consolidated in the newly expanded electronics and plastics laboratories.

Complete mechanical, electrical and chemical laboratories of the usual types round out the unusual variety of equipment available for instruction and research.

ADMISSION OF UNDERGRADUATES

New students at the Lowell Technological Institute are selected from those applicants who, during their preparatory education, have shown promise in scholastic ability and strength of character. In addition to scholastic rating and test results, a high value is placed on evidence of leadership and contributions to school and community life.

Application Procedure

Formal application for admission should be made as early as possible after the first marking period in the candidate's senior year of secondary school. Students from other countries are strongly advised to begin admission procedures not less than twelve months in advance of the expected date of enrollment.

Preliminary correspondence before the senior year is welcome and frequently helpful to the student in planning his secondary-school program to fit the needs of his freshman year at the Institute.

Requests for application blanks and all correspondence relating to matriculation at the Institute should be addressed to the Director of Admissions.

Steps to be taken for admission follow:

1. Pages one and two of the admission application form should be completed by the candidate.

2. Attach a certified check or money order in payment of the application fee of $10. (See "Student Expenses" for explanation.)

3. The whole application form should then be submitted to the office of the candidate's secondary-school principal, with the request that his office fill out pages three and four and mail the completed application directly to the Director of Admissions.

It is recommended that this procedure be accomplished as soon as possible in the candidate's senior year in secondary school so that he may be considered for admission to classes beginning the next September.

4. All candidates for scholarships should make direct application to the College Entrance Examination Board, P. O. Box 592, Princeton, New Jersey, with a request to take the Scholastic Aptitude Test, described later in this section. In addition, a formal application for a scholarship must be made with the Institute.

5. Each applicant must submit to a complete health examination by his family physician. A certificate of good health, indicating the date of this examination, must then be sent by the physician

to the Director of Admissions. The Institute has prepared a special form for the convenience of the physician; a copy of this certificate of health will be supplied.

6. A personal interview with the Director of Admissions is strongly recommended. The Office of Admissions at the Institute is open for this purpose Monday through Friday, from 8:30 A.M. to 4:00 P.M. during the school year. *It is urged that appointments for interviews be made in advance.*

Requirements for Admission

The Director of Admissions, in conjunction with the Committee on Admissions, reviews all applications to determine the eligibility of each candidate for matriculation. The final decision as to the eligibility of an applicant shall be left to the discretion of the Institute.

The conditions under which an applicant may be accepted are as follows:

1. A candidate for admission must be a graduate of a secondary school approved by the New England Entrance Certificate Board, the Regents of the State of New York, or a board of equal standing.

2. (a) Because of the specialized nature of the various curricula at Lowell Technological Institute, it has been deemed advisable that all entering students shall have completed the following units of secondary-school study:

algebra (quadratics and beyond)	2 units
plane geometry	1 unit
trigonometry	½ unit
English	4 units
American history	1 unit
chemistry (including laboratory)	1 unit
or	
physics (including laboratory)	1 unit

Preference will be given to applicants offering both chemistry and physics. In addition to the above-listed prerequisites, each applicant must offer credit in elective subjects, such as languages, other than English; history, other than American; mechanical drawing; solid geometry; advanced algebra; scientific subjects; social studies, and others.

(b) The combined prerequisites and electives should total at least 15½ Carnegie units. Each such unit of preparatory credit is the equivalent of one secondary-school subject satisfactorily pursued during one academic

year of at least thirty-six weeks of four forty-minute meetings each week, or the equivalent.

(c) In evaluating the credits offered by an applicant for admission, the Institute will be guided primarily by the quality of his scholastic record and by his apparent promise on grounds of intellect and character. Therefore, an applicant whose preparation has not followed the normal pattern with respect to the accumulation of unit credits should not hesitate to apply for entrance, provided that the quality of his scholarship gives evidence of ability to do college work and provided that he is recommended by his school. It is strongly recommended that the College Entrance Examination Board Scholastic Aptitude Test be taken to provide evidence of the candidate's ability to do college-level work.

3. All candidates for admission who are also applying for a scholarship must complete the Scholastic Aptitude Test which is prepared, administered, and graded independently of Lowell Technological Institute. Application to take the test must be made directly to the College Entrance Examination Board, P. O. Box 592, Princeton, New Jersey. Arrangements to take the test, no later than May, should be completed as early as possible in the candidate's senior year in secondary school. In addition, a formal application for a scholarship must be made with the Institute.

Admission with Advanced Standing

Transfer students must submit transcripts of their college record, a copy of their college catalogue and letters of honorable dismissal well in advance of their planned transfer date.

Transfer credit will be given for courses satisfactorily completed that are the equivalent in quality and scope of those given at the Institute. Final decision on transfer credit rests with the Divisional Chairman in charge of the subject for which transfer credit is desired.

Special Students

Qualified applicants may be accepted for specialized work not leading to a degree. The plan of study should have a clearly defined objective and should not deviate markedly from the regularly formulated subject matter and laboratory courses at the Institute. Admission as a special student is contingent upon approval by the Director of Admissions and the Divisional Chairmen concerned in the proposed program.

Students from Other Countries

Each year Lowell Technological Institute accepts for admission foreign applicants up to 5% of the total number of students in any given class (freshman, sophomore, etc.). There are no special procedures to be observed by foreign candidates, although it is urged that they endeavor to have the transcript of their secondary-school and/or college records, as well as all other admission materials, submitted, in English, *not less than twelve months in advance of the expected date of enrollment.* All applicants should have a considerable facility in speaking and writing English, and have financial resources sufficient at least for their first year of study. Foreign students will be expected to complete the same schedule of courses as is assigned to all other students.

In all respects, the admission procedures for foreign students are identical with those required of U. S. citizens.

To facilitate their adjustment to the life of the campus, all male students from other countries are required to live in the residence halls of the Institute and are assigned room space shared jointly with American students. Students attending for the first time should note that towels, sheets, pillowcases, and blankets must be supplied by occupants of rooms. Students are therefore reminded that bedding, as well as clothing, should be suitable for a climate in which temperatures normally fall well below the freezing point during the winter months.

STUDENT HOUSING AND SERVICES

Residence Halls

All male students are required to live in the residence halls unless excused in writing by the Dean of Students. These excuses are subject to review at the beginning of each semester and may be cancelled should conditions warrant.

Application for permission to occupy other living quarters will be made on special blanks available at the Dean of Students' Office. An application must be filed annually by each student. Deadlines for filing applications are: (a) for all new students (incoming freshmen, transfer students, special students, or graduate students)—on or before September 1 of each year; (b) for all regularly enrolled students—on or before June 1 of each year.

In granting special permission to live outside the residence halls, the Dean of Students will give full consideration to the following:

a. Distance from Institute to place of legal residence.
b. Financial hardships involved in living in residence hall.
c. Year of the student (freshman, sophomore, junior, senior, graduate).
d. Membership in fraternities that maintain a fraternity house.

Rooms are furnished by the Institute but are cared for by the students occupying them. Sheets, pillowcases, blankets, towels, and other personal linens must be supplied by each student. Each occupant is held responsible for any damage done to furniture and equipment.

Assignments of rooms in the residence halls are made through the Office of the Dean of Students for the full academic year. Change of room is not permitted except under unusual circumstances, and may be accomplished only after a formal application has been approved by the Dean of Students.

The uniform rental charge is $275 per academic year for each student. While this charge covers occupancy during periods that the Institute is regularly in session, it may, at the option of the Institute, be extended to vacation periods.

Assignments of rooms are made as equitably as possible and in the order that applications are received. For those students who are unable to be placed in residence halls, the Dean's Office supplies a list of approved rooming houses where students may reside.

Dining Hall

Dining facilities are provided on the campus in a cafeteria located on the ground floor of Smith Hall and in a snack bar located in the Students' Lounge in Eames Hall. These facilities provide additional opportunities for the students to become better acquainted as well as assuring wholesome food and a balanced diet.

Guidance

The guidance program begins with the admission procedures, continues throughout the undergraduate years, and culminates in the work of the Placement Office as outlined on page 53.

Guidance in the freshman year stems mainly from the results of the diagnostic testing program, Freshman Week activities, and conferences with the faculty throughout the freshman year. During the sophomore, junior and senior years the heads of departments and the Dean of Students take over the primary responsibility for the students' personal and scholastic guidance.

The Office of the Dean of Students is open to all undergraduates from 9 a.m. to 5 p.m. daily to assist the student in attaining his academic objective, and to assure his active, enjoyable participation in the work and affairs of the Institute.

Health Service

The dispensary, in Smith Hall, is in charge of a registered nurse eight hours each school day. She is on call twenty-four hours daily, including week ends. Students receive first-aid treatment at the dispensary, and are advised as to the best procedure in case of illness.

Medical services are available to the Institute twenty-four hours daily. If any student requires hospitalization, the college physician will arrange for admission to one of the three excellent, modern hospitals located in the immediate vicinity of the Institute. Medical fees and hospital charges are at the expense of the student.

Accident insurance during the academic year is compulsory and is included in the Activity and Insurance Fee. Sickness insurance is also available on a voluntary basis through the Office of the Dean of Students.

STUDENT REGULATIONS

Conduct

Students admitted to Lowell Technological Institute are assumed to be ladies and gentlemen and of sufficient maturity and poise to enable them to live in an adult environment. Such living involves full respect for the rights of others, a regard for self-discipline and good order, and a high standard of honesty and of moral conduct.

In consequence of these assumptions, the regulations are framed not to restrict the conduct of individuals or groups of students. They simply set forth the basic policies established by the Faculty in order that a large student body may live and work harmoniously together with a minimum of friction and misunderstanding. By the same token, even though the rules are neither detailed nor comprehensive, a student may be dropped from the rolls or subjected to other disciplinary action for conduct which is illegal, immoral, or inimical to the best interests of the Institute. This holds whether or not the particular offense is listed in these rules and regulations.

Attendance

Attendance is expected of all students at all classes. The supervision of student attendance is lodged in the Office of the Dean of Students, both as to the announcement of detailed instructions and the enforcement of the rules established by the Faculty. Students charged with unexcused absences, particularly absences immediately before and after holiday and vacation periods, are subject to disciplinary action.

Disciplinary Action

Disciplinary action originates in the Office of the Dean of Students. Such action may be in the form of any of the following degrees of severity: Censure, Restriction, Suspension, or Dismissal. Whenever disciplinary action is taken, a notation of such action becomes a part of the permanent record of the student.

Academic Grades

The students' grades are reported by letter as follows:

A	90-100	F	Below 60, Failure
B	80-89	I	Incomplete
C	70-79	W	Withdrawn
D	60-69	X	Dropped

The student's semester rating is a weighted value used to denote his relative standing. The point values assigned are A = 4 points, B = 3 points, C = 2 points, D = 1 point and F = 0 points. These point values, when multiplied by the credit hours assigned to the subject and added together, are divided by the sum of the credit hours to give the student's semester rating. The cumulative rating for more than one semester will be obtained in the same manner as the computation for the rating of a single semester.

Scholastic Reports

Reports of scholastic standing are compiled regularly at the end of each semester and formal notification of each student's status is made at that time.

Dean's List

The Dean's List is composed of those students who have a semester rating of 3.00 or higher, with no current failures.

Probation

A student is placed on probation when his semester rating is below 1.25. The probationary period covers the entire semester following the issuance of the semester rating which placed the student on probation.

A student on probation may not represent the Institute in any public function and may not hold class or other offices during his term of probation.

A student with a rating of less than 1.25 for two consecutive semesters shall be dropped from the Institute for at least one semester.

If a student receives a semester rating below 0.50, he shall be automatically dropped from the Institute without benefit of a probationary period.

REQUIREMENTS FOR GRADUATION

Only those students who have satisfied the following minimum requirements will be recommended for the baccalaureate:

(1) Complete successfully one of the prescribed curricula with no substitutions for major subjects therein and no unremoved failures in a major subject.

(2) Earn a cumulative rating of 1.5 or better for the entire period at the Institute.

(3) Pass 80% of the credit hours offered towards the degree with grades higher than D.

Graduation Honors

Academic honors are awarded at the annual Commencement Exercises by appropriate notation on the diplomas for the baccalaureate degree, and by printing in the Commencement program the names of students who have earned such recognition. Honors are awarded according to the following standards of achievement:

a. Any student who graduates with a rating of 3.00—3.49 for the entire period of study at the Institute shall be awarded the baccalaureate degree *"With Honors"*.

b. Any student who graduates with a rating of 3.5 or better for the entire period of study at the Institute shall be awarded the baccalaureate degree *"With High Honors"*.

c. The highest ranking student in each graduating class who graduates with a rating of 3.8 or better, and who has completed at least six semesters of work at the Institute, shall be awarded the baccalaureate degree *"With Highest Honors"*.

STUDENT AWARDS

The following awards are made annually by the Scholarship and Awards Committee:

(1) *American Association of Textile Chemists and Colorists Book Prize*

Awarded to the outstanding graduating senior in the course of Textile Chemistry. The recipient is recommended by the Chemistry Division and the academic standing of the candidate is an important factor. The award includes a junior membership for one year in the A.A.T.C.C.

(2) *American Association for Textile Technology Award*

Given annually to the member of the senior class majoring in textiles, who is rated highest on the basis of scholarship, technical ability, industry, judgment, leadership, reliability, and ability to work with others.

(3) *Chemistry Department Award*

A book prize is awarded to the member of the freshman class who shows the highest achievement in Freshman Chemistry during the first semester.

(4) *National Association of Cotton Manufacturers Award*

Given to the member of the graduating class in Textile Engineering (General Manufacturing Option) or Textile Technology

who has maintained the highest scholastic standing throughout the four years of his undergraduate work.

(5) *Louis A. Olney Book Prizes*

Selected reference books are awarded annually to the outstanding freshman, sophomore, and junior students in the course of Textile Chemistry. The recipients are recommended by the Chemistry Division chiefly on the basis of academic standing in chemical subjects.

(6) *Phi Psi Award*

Given annually to an outstanding member of the graduating class on the basis of scholastic standing, leadership, initiative, personality, loyalty, and courtesy.

(7) *President's Medal*

This award is made at Commencement to the student graduating with the most distinguished academic record in his class and *"With Highest Honors."*

(8) *Textile Veterans Association Honor Award*

This Association, representing all the veterans of World War II now affiliated with the textile and allied industries, has established an annual honor award, in the form of a suitably engraved bronze medallion. It is given to an outstanding graduating senior in a textile course on the basis of scholastic standing, extra-curricular activities, and over-all contribution to the Institute. Preference is given to veterans.

(9) *The Dean's Key*

This award, sponsored by the Student Council, is made annually to the member of the senior class who, in the eyes of a committee selected by the Dean of Students and composed of faculty and administrative personnel, has made the greatest extra-curricular contribution to the Institute during his four years of college.

STUDENT EXPENSES

The various student expenses described in this section apply only to the regular day school of Lowell Technological Institute. The fees and expenses of the Evening Division are described in a separate bulletin. All fees are established by the Board of Trustees and are subject to change without advance notice.

Payment of tuition and fees is an integral part of the registration process which must be completed before a student may attend classes. In special cases a delay in the payment of fees may be authorized, but all fees *must be paid* on or before the close of the sixth week of classes of the semester involved. Requests for delay must be approved *before* a student's registration is complete.

Application Fee (first year of registration only) . . . $10

Payable by certified check or money order and filed with the Director of Admissions at the time of application.

a. If the applicant is accepted for admission and is duly enrolled as a student at the Institute, the entire amount of this fee shall be credited toward his tuition charges on the day of registration.

b. If the applicant is not accepted for admission as a student, the entire amount of this fee shall be refunded.

c. If the applicant is accepted for admission but does not choose to enroll as a student, no refund shall be made.

d. If the applicant is accepted for admission but is called to duty in the Armed Services of the United States, he shall, upon presentation of suitable evidence of this fact, be entitled to a refund of the entire amount of the application fee.

Tuition—The yearly tuition fees are:

U. S. citizens who are residents of Massachusetts	$150
U. S. citizens who reside outside Massachusetts	$250
Citizens of other countries	$500

Students who are classified by the United States Immigration Authorities as "Displaced Persons" will pay non-residents' tuition of $250.

Applicants for admission from territorial possessions or protectorates of the United States will pay the tuition fees established for non-residents.

Special students pay, in general, the full tuition fee. However, if enrolled in only a limited number of courses, a special student may make application to the President for a reduction in tuition.

Residence

Because Lowell Technological Institute is a state-supported institution, its educational program and facilities are made available at a low tuition rate to students entering from the Commonwealth. Eligibility for admission as a resident entitled to the low residential tuition is determined under policies established by the Board of Trustees.

a. Every student claiming residence in Massachusetts must file with the Dean of Students a certificate signed by either the town or city clerk of the community claimed as legal residence, stating that the student's parents or guardian is a legal resident of the Commonwealth of Massachusetts.

b. The residence of a minor shall follow that of the parents, unless the minor has been emancipated. A minor student who has been emancipated shall, in addition to the requirements respecting residence, present satisfactory documentary evidence of emancipation.

c. A minor under guardianship shall be required to present satisfactory documentary evidence of the appointment of a guardian in addition to the certificate of residence of the guardian.

d. The residence of any applicant for admission, as shown on the application for admission at the time of initial application, shall determine the appropriate tuition charge to be made for the entire period or periods of the applicant's enrollment as an undergraduate, graduate, and/or special student.

e. The residence of a wife shall follow that of the husband.

f. The prescribed form of application for classification as to residence shall be executed by each student. Misrepresentation of facts to evade payment of the proper rate of tuition shall constitute sufficient cause for suspension or permanent separation from the Institute.

g. Payment of one-half of the total yearly tuition will be made during the registration for each semester.

h. The President of the Institute is authorized to adjust individual cases within the spirit of these rules.

Note: Wherever mentioned above, the word *residence* is considered to mean *legal domicile.*

ROTC Deposit $25

This deposit covers loss of, or damage to, uniform or equipment used for ROTC instruction. It is required of all students enrolled in ROTC. The entire amount, less charges, will be refunded upon the completion of the ROTC requirements. If, at any time, the charges against a student exceed the amount on deposit, the student will be required to pay such charges and to make an additional deposit of $25.

Activity and Insurance $40

Each student will pay $20 each semester of the academic year as a student activity and insurance fee. The payment of this fee entitles the student to free admission to all athletic events, a mailbox in the campus post office, a subscription to the student newspaper, and a copy of the yearbook. A portion of this fee helps to support the general student activities under the jurisdiction of the Student Council. It pays for the compulsory accident insurance policy which covers each student against accidents during the academic year and also contains a compulsory bonding fee which protects the Institute against unpaid student charges.

Residence Halls $275

All students, except those who live in Lowell or the surrounding community, may be required to live in one of the residence halls (see page 23 for details). The double rooms rent for $275 per student per year. One-half of the rent ($137.50) is payable at the start of each semester.

Laboratory and Materials Fee

To cover the cost of materials and normal breakage in all laboratories, each student will be charged as follows:

All freshmen $12/semester

Upperclassmen enrolled in:

(a) Textile Technology, Textile Engineering, Textile Sales, General Engineering, or Electronic Engineering . $12/semester

(b) Paper, Leather, or Plastics Engineering $17/semester

(c) Textile Chemistry $22/semester

The above charges are not refundable. Excess breakage will be billed direct to the student. These fees are payable each semester regardless of the number of laboratories taken and represent an average flat charge per semester for the regular four-year program in each of the above courses.

The above fee must be paid before a student can be admitted to laboratory work.

Commencement Fee (Seniors only) $15

This covers Commencement expenses such as degree and case, rental of cap and gown, invitations, printing and such other expenses as shall be approved or directed by the President.

Late Registration Fee $5

Any student who does not complete his registration (including the payment of all fees) by the close of the registration period may be required to pay an additional fee of $5.

Official Transcript Fee $1/copy

Each student will be allowed free of charge a total of three transcripts of his scholastic record. A charge of $1 per copy will be made for each *additional* transcript.

Auditing Fee . . . . $5/credit hour

All students regularly enrolled and paying the full tuition charge in any semester may audit courses in that semester without charge providing proper approval is obtained.

Students not regularly enrolled or not paying the full tuition charge for the semester must pay $5 per credit hour to audit a course and must obtain proper approval.

Books and Materials—Students must provide their own books, stationery, tools, etc., and pay for any breakage or damage that they cause to machines, laboratory equipment, and other property of Lowell Technological Institute.

All raw stock and yarn furnished to the students, and all the productions of the Institute, remain or become its property, except by special arrangement, but each student is allowed to retain specimens of yarn or fabrics that he has produced, if mounted and tabulated in accordance with the requirements of the department. It is understood that the departments may retain such specimens of students' work as they may determine.

No books, instruments, or other property of the Institute loaned to the students are to be removed from the premises except by special permission.

Refund Schedule—Applications for refunds, filed with the Bursar on withdrawal, will be made in accordance with the following table:

No. of Weeks *At least*	*But less than*	*Refund Rate*
0	2	80%
2	3	60%
3	4	40%
4	5	20%
5 and over		None

Summary of Expenses Per Year

Tuition (residents of Massachusetts)	$150
Tuition (residents of other states and U. S. Possessions)	250
Tuition (residents of other countries)	500
Dormitory rate	275
Laboratory and Materials Fee	
(a) All freshmen	24
(b) Upperclassmen enrolled in:	
Textile Technology, Textile Engineering, Textile Sales, General Engineering, or Electronic Engineering	24
Paper, Leather, or Plastics Engineering	34
Textile Chemistry	44
Student Activity and Insurance Fee	40
ROTC Deposit	25
*Books and supplies	50

*Books and supplies for the first year cost about $80, second and third year $35, and fourth year $50, thus averaging about $50 per year for the four years.

STUDENT ACTIVITIES

Lowell Technological Institute believes that sound educational practice seeks to develop the whole personality of the student. Accordingly, Faculty and Administration encourage extra-curricular activities and support the development of a varied and well-rounded program of activities to supplement the purely academic phase of undergraduate life. This program provides opportunity for participation in formal and informal sports, in class and campus self-government, and in the many clubs and special interest activities which appeal to the varied interests of the student body.

Student Council

The Student Council is the chief body for the conduct of self-government in student affairs. It is composed of four officers elected at large by the student body, the president of each undergraduate class, and one representative from each of the classes.

By virtue of its function as chief governing body for student affairs, it exercises administrative control over all campus organizations formed under its supervision; represents the student body in matters requiring conference with the Administration and Faculty; investigates grievances submitted by students or student groups; sponsors all-campus dances, banquets, and other social affairs; and supervises the expenditure of the unallocated portion of the Student Activity Fee. It functions in accordance with the specific prescriptions of its Constitution and By-Laws.

Athletics

The Athletic Association promotes an extensive varsity and intramural sports program. All students are members of the Athletic Association and receive free admission to all intercollegiate contests played at home.

Soccer, basketball and baseball are varsity sports at the Institute. Competition is chiefly with teams in the northeast portion of the country. Lacrosse, golf, tennis and ski teams also compete regularly with other colleges in the area.

Intramural sports are sponsored by the Director of Intramural Athletics with an interesting year-long program of both league and informal competition between the classes, residence halls, and fraternities.

Band

The AFROTC Band is composed primarily of cadets who are musicians or who desire to learn to play a band instrument. In addition to providing the music for the AFROTC ceremonies, the band adds considerably to the color and life of the campus by participating in various Institute and civic programs.

Circle K

The Circle K club is the student chapter of the Kiwanis at the Institute. In addition to performing many services in the public interest, it assists the administration of the Institute in the freshman orientation program each year.

Duplicate Bridge Club

The Duplicate Bridge Club is open to all students and faculty members at the Institute. The club has approximately ten playing sessions per year to determine the championship team. Student members also participate in the annual national Intercollegiate Duplicate Bridge Tournament.

Film Group

Under the sponsorship of the Tech Players, the Film Group presents a series of foreign and American film classics each year to subscribers and their guests.

Flying Club

The Flying Club is operated on a corporate basis and is open to all students and faculty members. An aircraft is maintained at a local airport for purposes of instruction and solo flights for qualified members. All AFROTC members who solo successfully are awarded AFROTC wings.

Fraternities

The Interfraternity Council fosters the common interests of the four fraternity chapters at the Institute. This organization sponsors joint social and athletic contests among the fraternities.

The four fraternities have their own houses for fraternity socials and meetings, providing centers for the social life off the campus. The fraternities are: Delta Kappa Phi, Omicron Pi, Phi Psi, and Pi Lambda Phi.

General Vandenberg Air Society

The purpose of the General Vandenberg Air Society is to unite selected advanced AFROTC cadets by a fraternal bond in order to further the mission and traditions of the Air Force. The Society is affiliated with the Air Force Association which further extends the fraternal bond to include air-minded individuals. A squadron of the General Vandenberg Air Society has been established at this Institute and is a chapter of the National Society. The Society is responsible for a cadet sports program and a variety of social affairs during the academic year. The Military Week End, the Society's social highlight, features a colorful drill ceremony and has as its climax the formal Military Ball at which announcement of the cadet officers is made.

International Students Circle

This club lists all foreign students at the Institute as its members. It serves to bring into close contact all these students who may have some difficulty in becoming adjusted to a new language or way of living. These students are in demand by local civic groups to serve as speakers on many programs.

The Nucleus

The club was initiated to serve as a focal point for students to meet and present ideas and reports regarding actual activities in industry. The club has a membership limit of fifteen members who are the leaders of all the major activities on the campus. A high scholastic rating is also a prime requisite for active participation.

"Pickout"

The "Pickout" is the annual yearbook of the campus. Those who serve on the staff secure a valuable training in the editorial, art, and business problems involved in the production of a top-quality photo-literary history of the academic year.

Professional Societies

The following societies conduct monthly meetings at which students and outstanding speakers present technical papers and lectures. Frequent field trips to industrial plants are also made by the members. These societies include:

(1) American Association of Textile Chemists and Colorists.
(2) American Society of Mechanical Engineers, Student Chapter.
(3) Electronic Engineering Society.
(4) Engineering Society.
(5) Leather Engineering Society.
(6) Paper Engineering Society.
(7) Plastics Engineering Society.
(8) Textile Society.

Radio Station

The Radio Station (WLTI) is an all-student enterprise built and maintained by members of the Lowell Technological Institute Broadcasting Society. Programs are transmitted by a carrier current to the buildings of the campus from the station studio.

The radio station sells air time to local merchants and thus is a self-supporting organization. It provides a fine opportunity for students to learn business practices as well as broadcasting and radio techniques.

Religious Groups

Hillel. The Hillel Counsellorship was established to provide social, cultural and religious programs for the Jewish students at the Institute. Discussion groups are held weekly and brunches or dances monthly. Speakers are invited to talk on subjects of interest to the whole student body. Hillel groups, located at most of the larger colleges and universities, are sponsored by the national B'nai B'rith organization.

Iona Student Fellowship. A group composed of students and faculty members of various races and creeds who, by uniting in a common fellowship, attempt to understand the will of God through worship, study and action, and thus realize it both in personal living and in working toward a better society.

Newman Club. The Newman Club is an organization sponsored by the Catholic students at the Institute. It conducts programs of a social and religious nature.

Rifle Team

The AFROTC Rifle Team is open to all AFROTC cadets. Competent staff members train the group, with the aid of National Rifle Association members, for intercollegiate competition matches.

The major match of the year is the William Randolph Hearst Trophy Match.

Scholastic Honor Society

Membership in Tau Epsilon Sigma is open to members of the Junior and Senior Classes who are elected on the basis of outstanding scholastic achievement and character.

Sorority

The Sorority Phi Sigma Rho provides a center for the social life and association of the young women enrolled in the various programs of the Institute.

T.O.C.

The Tech Orientation Committee has as its special function the introduction of the new student to college life. During Orientation Week, the first week of school for the freshmen, a series of activities is planned by T.O.C. to enable freshman class members to meet each other and to realize their responsibilities to their college.

Tech Players

All the theatrical activities of the Institute are centered around the Tech Players. For years the annual production of this group has been a high point in the social calendar.

"The Text"

"The Text" is the campus newspaper. Prepared and edited by the students, this bi-weekly publication offers excellent journalistic and business experience to those who work on its staff.

Varsity Club

This club is composed of students who have earned letters in any of the six intercollegiate sports, namely, baseball, basketball, golf, lacrosse, soccer and tennis. Its purpose is to help athletes academically and to foster a lasting friendship among the men participating in athletics.

FINANCIAL AID TO STUDENTS

SCHOLARSHIPS

A large number of scholarships are available to students and prospective students at Lowell Technological Institute through funds contributed by various trusts, organizations, civic bodies and industrial firms. Many of the scholarships are renewable yearly for the balance of the student's undergraduate program, provided a satisfactory scholastic average is maintained; others are only for a specified period of time.

All entering freshmen who are candidates for scholarships should make direct application to the Director of Admissions, Lowell Technological Institute, Lowell, Massachusetts, before June 1 and must have completed the Scholastic Aptitude test of the College Entrance Examination Board by May 1. To arrange for this test, candidates must also make direct application to the College Entrance Examination Board, P. O. Box 592, Princeton, New Jersey, with a request to take the Scholastic Aptitude test.

Unless otherwise specified, all scholarships will be granted by vote of the Scholarship and Awards Committee of the Institute. Any student holding a scholarship must remain in good standing in college and progress normally from year to year. While honor grades are not required, scholarship holders are expected to do scholarship-level college work. Grades which prevent normal progress or conduct which results in probation, suspension, or dismissal, terminates the scholarship.

Available for Freshmen and Upperclassmen

1. Albany Felt Company Scholarship

One annual grant to Lowell Technological Institute in the amount of $500 to an entering freshman is made by the Albany Felt Company. Recipients of these scholarships will be offered the opportunity for summer employment at the Albany Felt Company while in college.

2. Alumni Association Scholarships—Lowell Technological Institute

Scholarship funds under the care of the Alumni Association make available several scholarships a year which cover tuition and

miscellaneous fees. These scholarships are renewable if a satisfactory scholastic standing is maintained.

3. Berkshire Hathaway, Inc. Scholarship

A number of scholarships covering tuition and living expenses for four years are offered in textile engineering and technology by Berkshire Hathaway, Inc., Providence, Rhode Island. Eligible applicants are:

a. Male employees of Berkshire Hathaway, Inc. who have had adequate secondary-school training.

b. High-school graduates who are sons of present employees.

Interested students should contact Berkshire Hathaway, Inc., 704 Hospital Trust Building, Providence 1, Rhode Island.

4. Russell L. Brown Scholarship—donated by Davis and Furber Machine Company

This scholarship is open to a student acceptable to Lowell Technological Institute who plans to enroll in the curriculum of textile engineering or textile technology. Preference is given to employees and sons or grandsons of employees of Davis and Furber Machine Company. The selection is based on general scholarship, initiative, and need. The stipend is $300. The appointments are for one year only but are renewable.

5. Caron Spinning Company Scholarship

This scholarship is awarded to employees or to relatives of employees of the Caron Spinning Company and to graduates of Rochelle, Illinois, High School, on the basis of general scholarship, initiative, and character. The amount of the scholarship is $1,250 each year, and it is awarded on a four-year basis provided satisfactory academic standing is maintained. Application should be made directly to Caron Spinning Company, Rochelle, Illinois.

6. Samuel P. Kaplan Memorial Fund Scholarships

The New England Knitted Outerwear Manufacturers' Association has set up a fund in memory of Samuel P. Kaplan to enable two prizes to be awarded each year to outstanding students in the basic knitting course. An award of $100 will be granted to the highest-ranking student at the end of the first semester and a similar award will be made at the end of the second semester.

7. Joseph Kaplan Scholarship

This $250 scholarship was established by a fund set up by Joseph Kaplan, to be awarded annually to the winner of Techno-

rama, a science fair for Merrimack Valley high schools held each year at the Institute.

8. A. C. Lawrence Leather Company Scholarship

The A. C. Lawrence Leather Company in Peabody, Massachusetts, makes available a $500 scholarship on a one-year basis to a student in leather engineering at Lowell Technological Institute. Preference is given to an employee or member of an employee's family, or to a resident in a town in which the Company operates. If no eligible applicants are available, the award will be open to any member of the Leather Engineering Department on the basis of merit.

9. Leather Engineering Department Scholarships

The Leather Engineering Department has funds for several scholarships and awards under its jurisdiction which it periodically releases for scholastic aid purposes through the Institute Scholarship Committee. These funds have been made available by interested industrial firms and trade organizations. These scholarships are available to deserving students enrolled in the Leather Engineering course who need financial assistance for scholastic purposes.

10. City of Lowell Scholarships

The City of Lowell has appropriated funds to provide a total of five scholarships every two-year period. These scholarships are awarded on the basis of competitive examinations to residents of the City of Lowell, Massachusetts, who are enrolled in the freshman class at the Institute. The amount of the scholarship is $150, which is full tuition at the Institute, and it is renewable provided satisfactory scholastic grades are maintained.

11. Commonwealth of Massachusetts Scholarships

Ten scholarships of $250 each year are available for young men and women who are residents of the Commonwealth of Massachusetts and are enrolled in the freshman class at the Institute. Awards are made on the basis of competitive examinations and the scholarships are renewable provided satisfactory grades are maintained.

12. The McLaurin-Jones Company Scholarship

This scholarship is awarded annually to a member of the Tantasqua Regional High School in Framingham, Mass., the Ware, Mass., High School, or the Homer, Louisiana, High School graduating class, or to an employee or son of an employee of the Ludlow Papers Company (formerly the McLaurin-Jones Company) for work

in the Paper Engineering Department. The scholarship for $500 is renewable from year to year for four years if a satisfactory scholastic record is maintained.

13. Mohawk Carpet Mills Textile Scholarship

A $2,000 scholarship has been made available to high-school graduates or employees of the Mohawk Carpet Mills who are residents of New York State. All applicants must have applied for enrollment in one of the various textile courses at the Institute in order to be eligible. Application must be made to the Mohawk Carpet Mills, Inc., Amsterdam, New York.

14. New England Tanners Club Scholarship

This scholarship is awarded by annual vote of the New England Tanners Club and is granted to a student in Leather Engineering at Lowell Technological Institute. Preference is given to employees of the member companies of the New England Tanners Club or to their families. If no eligible applicants are available, awards will be open to others on the basis of secondary-school scholastic performance and evidence of potential leadership. The amount of the scholarship is $1,000, awarded on a one-year basis.

15. New England Textile Foundation Undergraduate Scholarships

No further awards.

16. Dr. Geoffrey R. Broughton Paper Engineering Scholarship

A scholarship prize of $100 is awarded at the beginning of the spring semester to the member of the freshman class who achieves the highest scholastic standing. The prize is made available by a number of interested companies for students enrolled in the Paper Engineering Department.

17. Salem Oil & Grease Company Scholarships

Normally, two scholarships of $500 each are available each year through the Salem Oil & Grease Company in Salem, Massachusetts, which established the awards as a memorial to the late Harold T. N. Smith, a founder of the company. These are allocated to candidates enrolled in the Department of Leather Engineering depending on scholastic ability and financial need.

18. Shapiro Brothers Factors Corporation Awards

Two $500 scholarships are given each year through the Shapiro Scholarship Fund, Inc. of New York City. The criteria governing these scholarships are financial need and scholastic ability.

19. Society of Plastics Engineers Scholarship

This is a $200 scholarship, given by the Eastern New England Section of the Society of Plastics Engineers, Inc., to be awarded to a deserving sophomore majoring in Plastics Engineering. The student will be selected by the Lowell Technological Institute Scholarship and Awards Committee.

20. Sylvan I. Stroock Scholarship—S. Stroock & Co., Inc.

Awards are made on the basis of scholarship, financial need, leadership, and promise of success in textile fields. The sum available for scholarship purposes is $500 per year, offered annually at the discretion of the Scholarship Committee.

21. H. Webster Thomas Memorial Scholarship—donated by the Rohm and Haas Corporation of Philadelphia, Pennsylvania

This scholarship is awarded for a four-year period to a student in Leather Engineering at Lowell Technological Institute. The amount of the scholarship is $500 per year.

22. United Elastic Corporation Scholarships

Scholarships in the amount of $250 are available to students taking one of the various textile courses through the United Elastic Corporation, Easthampton, Massachusetts.

These scholarships have been established primarily for employees of the United Elastic Corporation, or members of their families. Other residents of the communities where plants are located, however, may enter applications for consideration. Preference is given to native New Englanders and to those who agree to work summers in approved mills.

Qualifications for scholarships include good character and standing in the community, aptitude for technical training, and ability to pass entrance requirements of Lowell Technological Institute. With the approval of the United Elastic Corporation and the Lowell Technological Institute, scholarships may be awarded to deserving upperclassmen.

Each scholarship is for a one-year period and further extension if the performance of the student during the year is satisfactory. The United Elastic Corporation will, so far as possible, furnish suitable employment to the student during the summer vacation period and following graduation.

All applications should be made through the plant nearest the residence of the applicant. Plants are located at Easthampton, Lowell, and Littleton, Massachusetts; West Haven, Connecticut; and Stuart, Virginia.

23. Jacob Ziskind Memorial Fund for Freshmen

This scholarship was established by the employees of the Merrimack Manufacturing Company in memory of Jacob Ziskind, and is applicable to freshmen only.

Qualifications for the scholarship include good character, scholastic record, initiative and ability to pass the entrance requirements at Lowell Technological Institute. Preference in granting the scholarship is given to employees of the Merrimack Manufacturing Company or members of their immediate families residing in the Greater-Lowell area. However, other residents of Greater-Lowell may enter applications for consideration.

Available for Upperclassmen Only

1. Alliance Color and Chemical Company Scholarship

This four-year scholarship amounting to $500 annually is granted by the Alliance Color and Chemical Company to any student majoring in textile chemistry with particular emphasis on textile dyeing. It is awarded on the basis of ability, need, and character to a junior or senior whose marks for his prior years in college have placed him in at least the top third of his class. This sum may be applied against tuition or room and board but shall not be in addition to any other scholarship award.

2. American Textile Machinery Association Scholarship

The Institute Board of Trustees has established an American Textile Machinery Association scholarship of $150, to be awarded to a qualified student majoring in textiles.

3. American Viscose Corporation Scholarship

This undergraduate scholarship amounting to $500 is granted by the American Viscose Corporation for one year only to a promising junior or senior student majoring in textile technology.

4. Arthur Besse Memorial Scholarship

The scholarship is awarded by the Arthur Besse Memorial Trust to a student majoring in woolen and worsted manufacturing and planning to continue in that industry after graduation. Awards are based on need, scholarship, and qualities of character and leadership. The amount of the scholarship is $500 a year, and is renewable if a satisfactory scholastic record is maintained.

5. Boston Paper Trade Association Scholarship

This scholarship is open to any sophomore, junior, or senior enrolled in the Paper Engineering Department who is a resident of New England. It is awarded on the basis of scholarship and general character. The amount of the scholarship is $150. It is anticipated that the scholarship will be made renewable each year by the Association.

6. Burlington Industries Foundation Scholarship

One of the newly instituted Burlington Industries Foundation scholarships will be available at the Institute for the second time in connection with the 1957-1958 academic year. It is valued at $1000, payable $500 a year for the junior and senior years of the student selected by the Institute on the basis of his leadership, scholarship and financial need.

7. Ciba Company, Inc., Scholarship

This scholarship, donated by the Ciba Company, Inc., is in the amount of $500 each for a junior and a senior in the textile dyeing and chemistry course at the Institute. Selection is based upon scholastic prowess.

8. Fiberglas Scholarship—Owens-Corning Fiberglas Corporation

This scholarship is awarded annually to an outstanding sophomore in any of the textile courses. It pays the recipient full tuition and $500 per academic year for each of the junior and senior years. Selection is based upon academic record, character, qualities of leadership, and need.

9. The Gehring Foundation Memorial Scholarships—in memory of Henry G. Gehring and his son, Edward H. Gehring, both of whom were engaged in the lace industry.

These scholarships are made possible as a result of the Gehring Memorial Foundation of New York. Selection of recipients made by the Scholarship Committee may be reviewed by the Gehring Foundation. The amount of the scholarship is $75 per semester and is renewable if a satisfactory scholastic record is maintained.

10. Ralph E. Hale Scholarship

This scholarship was established by the Northern New England Section of the American Association of Textile Chemists and Colorists in memory of Ralph E. Hale, 1951 Chairman-elect of the

Section and a 1931 graduate of L.T.I. This scholarship is awarded annually to a student at the completion of the junior year in the course in textile chemistry. The amount of the scholarship is $250 per year.

11. Interchemical Corporation Scholarships

Two $250 scholarships have been made available by the Interchemical Corporation of Pawtucket, Rhode Island, upon completion of two years of undergraduate work at Lowell Technological Institute. They are awarded on the basis of scholastic achievement, character, and leadership potential. Preference is given to textile chemistry majors.

12. New England Paper Merchants Association Scholarships

Two scholarships are open to any sophomores, juniors or seniors in the Paper Engineering Department who are residents of New England. They are awarded on the basis of scholarship and general character. The amount of each is $150. It is anticipated that they will be made renewable each year by the Association.

13. Dr. Geoffrey R. Broughton Paper Engineering Scholarships

Three prizes of $100 each are awarded at the beginning of each fall semester to the top ranking students enrolled in each of the sophomore, junior and senior classes of paper engineering.

Three prizes of $100 each are awarded at the beginning of each spring semester on the same basis. These prizes were made available by a number of interested companies for students enrolled in the Paper Engineering Department.

14. Jacob Ziskind Memorial Scholarship Fund

This scholarship was established by the Trustees of the Jacob Ziskind Trust for Charitable Purposes. Scholarships are awarded annually and are renewed provided a satisfactory scholastic record is maintained. The scholarship includes tuition, books, supplies and such other expenses as are required to enroll a student in his course. Recipients are selected by the Faculty Scholarship Committee and must have demonstrated high scholarship, financial need, and qualities of good character and leadership. Students from the sophomore, junior, and senior classes are eligible. Preference shall be given to, but not restricted to, those students who have received in their freshman year the Jacob Ziskind Memorial Fund for Freshmen.

LOAN FUND

A loan fund is available for the purpose of assisting upperclassmen to continue their education at Lowell Technological Institute. Students may make application for a loan through the Faculty Treasurer of the Lowell Textile Associates, Incorporated.

Repayments on any loan which are made while the student is still in school are interest free. Loans repaid after the student leaves school (for whatever reason) bear 4% interest beginning three months after the date on which the student officially leaves school. Repayments are not required until the student separates from Lowell Technological Institute, at which time repayments are due quarterly at a rate of $10 per quarter the first year and $20 per quarter each year thereafter until the loan is repaid. Additional payments may be made at any time so as to reduce indebtedness at a more rapid rate.

FELLOWSHIPS

A number of fellowships are available to students pursuing graduate studies.

1. Teaching Fellowships

Each year Lowell Technological Institute has available through the Commonwealth of Massachusetts a limited number of teaching fellowships for qualified students in the Graduate School who are working toward the Master of Science degree in textile chemistry or textile engineering. Appointees normally carry a half-time study load and are required to spend 12 to 15 hours per week in the supervision of undergraduate laboratories and review sections. The annual stipend is about $1500 with reappointment for a second year contingent on satisfactory performance of duties. Application forms may be obtained from, and must be filed prior to April 30 with, the Director of Graduate School at Lowell Technological Institute. Appointments will be made June 1 for the next academic year.

2. Research Fellowships

A limited number of Research Fellowships are also available to qualified graduate students through the Celanese Corporation of America, Linde Air Products Company, and National Aniline. These fellowships are principally in the Division of Chemistry for students who are working toward the Master of Science degree in textile chemistry. Research under these fellowships may involve

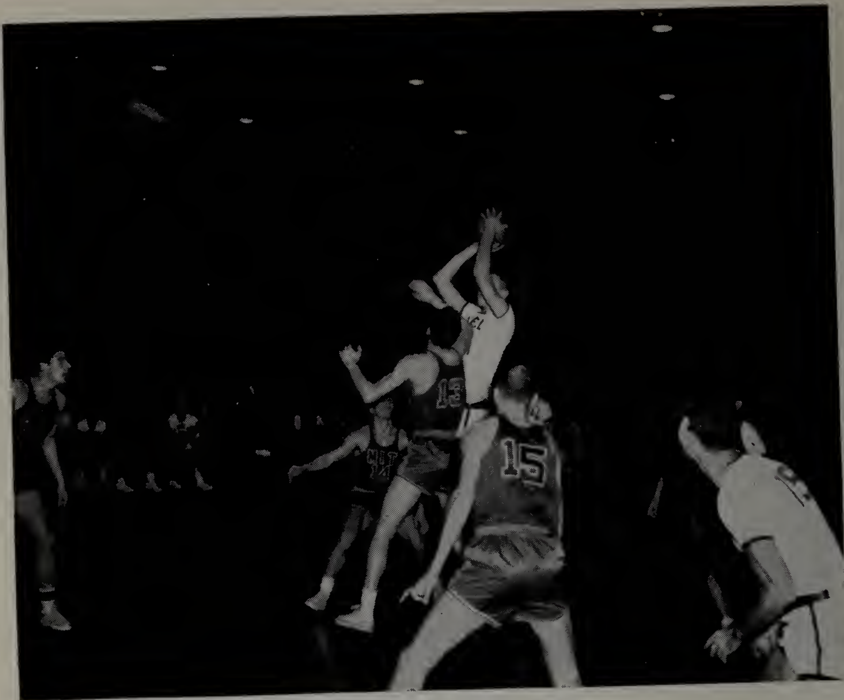
either fundamental or applied chemistry. Appointees are expected to devote full time to study and research. The stipends are $1200-$1500 per year. Application forms may be obtained from, and must be filed prior to April 30 with, the Director of Graduate School at Lowell Technological Institute. Appointments will be made June 1 for the next academic year.

3. Coats and Clark Inc. Fellowship

This fellowship is available only to graduates of textile colleges. It is made available for graduate work at the Massachusetts Institute of Technology and pays approximately $700 per year plus tuition. Application should be made directly to M.I.T.

Cumnock Hall — Newest Campus Building

Fraternity Men at Ease



Basketball Victory

Coeds at Leisure

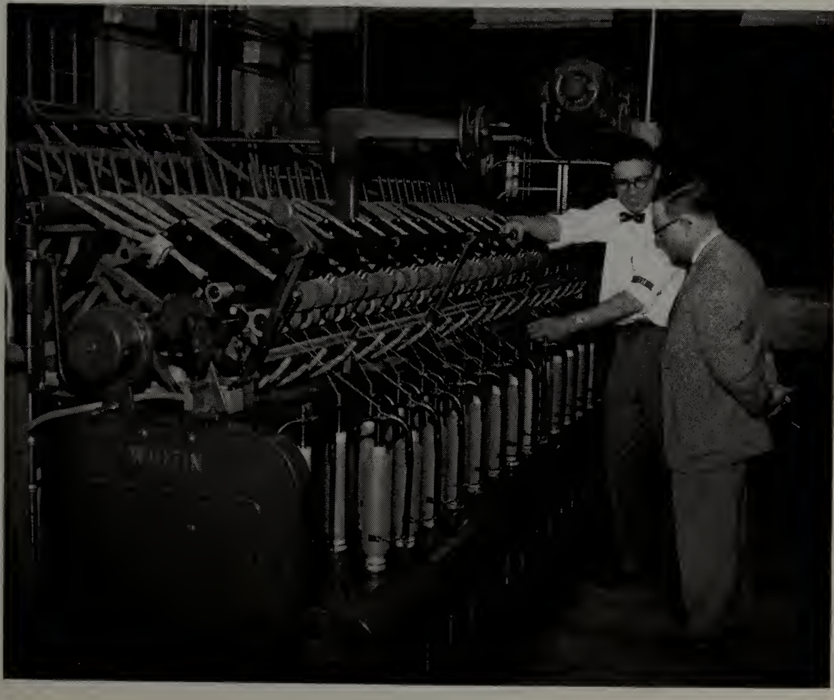

Medical Attention


Cafeteria

Informal AFROTC Briefing Session

LTI AFROTC Cadet on Field Trip

In Leather Engineering Laboratory

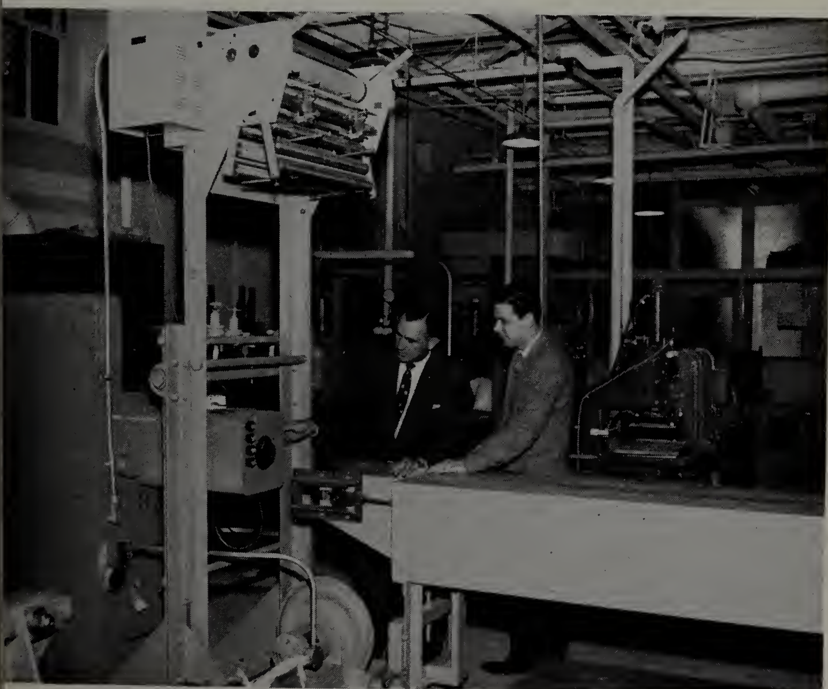


Yarn Processing

Physical Chemistry Experiment

Engineering Graphics Class

Paper Engineering Laboratory



Plastics Laboratory

Electronic Engineers

Amateur Radio Station

THE AIR FORCE ROTC UNIT

An Air Force Reserve Officers Training Corps unit was established at the Lowell Technological Institute on July 1, 1951. Instruction began with the opening of the first semester of the academic year 1951-52.

By vote of the Board of Trustees, all able-bodied non-veteran male students enrolling in Lowell Technological Institute for the first time on or after September 13, 1951 must satisfactorily complete the basic ROTC work (freshman and sophomore years) before receiving a Bachelor of Science degree. The President of the Institute may waive this requirement and permit the substitution of an equivalent amount of work only for those individuals who are not liable to military service under existing laws and regulations (for example, not a citizen of the United States, previous military service, etc.).

Uniforms and all equipment and textbooks required for the ROTC work will be supplied by the United States Air Force. Students in the Advanced Course will receive the standard cash payment allowed by the Air Force in lieu of subsistence.

Mission

The mission of the AFROTC unit is to develop in each cadet those attributes essential to his progressive advancement to a commission as a Second Lieutenant in the United States Air Force Reserve and further, to prepare him to fill positions of increasing responsibility as a commissioned officer in such duties in the Air Force as may be required by the national defense effort.

The AFROTC program takes into consideration the fact that many of the academic subjects in which Institute students are enrolled have as much direct relationship to military duties as they have to a civilian career. The courses contained in the AFROTC curriculum have been carefully selected to augment those academic subjects. The purpose of this course of instruction, then, is to enhance the otherwise high qualifications of the student with a thorough Air Force background.

Basic Course

The work covered in the first two years is considered the Basic Course. In addition to exercises in Leadership and Drill, this work includes classroom instruction in the Airplane and the Air Age, and the Elements and Potentials of Air Power. As stated

above, the satisfactory completion of the Basic Course is a requirement for the Bachelor of Science degree in all courses offered at the Institute. Cadets who satisfactorily complete the Basic Course may apply for the Advanced Course subject to approval by the Selection Board.

Advanced Course

The Advanced Course, consisting of the last two years of Air Force ROTC instruction supplemented by a summer camp, is designed to develop in the student to the highest degree possible those understandings, attitudes, skills and attributes of leadership considered essential in the development of all Air Force commissioned officers.

Air Science III, taught during the student's junior year, analyzes such problems as command and staff concepts; leadership laboratory; problem-solving techniques; communications process; principles and techniques of learning and teaching; Air Force correspondence and publications; military law and courts, and boards; applied air science, including aerial navigation, weather, and functions of the Air Force Base.

Air Science IV, taught during the student's senior year, contains a review of the previous years of air science; a critique of the Summer Camp training; leadership and management; military aspects of world political geography; principles of management; military aviation and the art of war; career guidance; and briefing for commissioned service.

Normally, students who successfully complete the Advanced Course are commissioned as second lieutenants in the United States Air Force Reserve and subsequently receive training as pilots or aerial observers. A limited number of students who show outstanding capability in non-flying engineering skills are also awarded commissions.

Summer Camp

In addition to completing satisfactorily the subjects required in the above generalized curriculum, each cadet enrolled in the Advanced Course is required to supplement his training by attending a summer camp of approximately four weeks duration. Usually this camp is attended during the summer preceding his senior year. Transportation from the legal residence of the cadet to the camp and return, uniforms, food, lodging, and medical and dental care are provided by the Air Force and, in addition, the cadet receives the pay of a basic airman.

Field Trips

Periodically, the Department of Air Science conducts field trips to various Air Force installations for the purpose of orientation. These trips include tours of the base and familiarization flights. Efforts are made also to assist those cadets who are interested in flying to gain as much information as possible about the operational phase of the Air Force.

Veterans

A veteran who qualifies for and completes successfully the Advanced Course of AFROTC will be commissioned a second lieutenant in the Air Force Reserve. Under present Air Force regulations, there is no requirement for an active duty tour; however, a veteran AFROTC graduate may apply for active duty as an officer. The Professor of Air Science may waive, in consideration of military service, portions of the Basic Course which cannot be completed prior to entrance into the Advanced Course.

Contributions to Student Life

In addition to the military and academic phases of its program, the Department of Air Science sponsors various extra-curricular activities which are designed to produce a well-rounded cadet. Much of this activity is undertaken by the General Vandenberg Air Society.

Cadet Decorations and Awards

A number of medals are awarded to selected cadets and cadet officers at a special Parade and Review held each spring.

Thomas F. Costello Trophy—Awarded to the AS IV cadet from the Lowell area displaying an outstanding degree of leadership, ability, resourcefulness, and academic excellence.

Alumni Medal—Awarded annually to the most outstanding cadet, regardless of class, for superior Air Science academic and extracurricular achievement.

Air Force Association Medal—Awarded to the outstanding AS IV cadet on the basis of four-year achievement.

Chicago Tribune Awards—Gold Medal awarded to the outstanding cadet in the Advanced Course. Silver Medal awarded to the outstanding cadet in the Basic Course.

Convair Award—Awarded for over-all contribution to the nation's air strength.

Republic Aviation Award—Awarded to the cadet making the most effective public presentation on an air power theme.

Reserve Officers Association Medal—Awarded to the AS IV cadet distinguishing himself for leadership, excellence of character, initiative, force, personality, neatness, discipline, and other related traits.

Sons of the Revolution Medal—Awarded to the basic cadet distinguishing himself in leadership, military bearing, and academic excellence.

Distinguished Military Graduate Award—Awarded to the outstanding AFROTC graduate. The recipient of this award may apply for a regular commission as a second lieutenant in the United States Air Force.

PLACEMENT

Industrial Training Program

The Placement Bureau with the assistance of Industry endeavors to place every qualified underclassman during the summer vacation periods in an industrial position similar to the student's major field of interest at the Institute. These training opportunities are available in chemistry, electronics, leather, paper, and textiles, and are open to all students who have completed their sophomore year except those on scholastic or disciplinary probation.

The objectives of the undergraduate Industrial Training Program are:

(1) To help supply essential industrial experience to the undergraduate;

(2) To provide experience in human engineering only obtained in Industry;

(3) To furnish an employment pool enabling industry to preview individual students;

(4) To further the liaison between the Institute and Industry.

Placement Service

The Placement Bureau maintains active contacts with a number of industrial firms throughout the country in each of the fields of engineering presented at the Institute. A complete file of opportunities and data on various industries and companies is available to the members of the graduating class in the Placement Office.

The Placement Bureau arranges for the visits of representatives from industrial firms to interview students. A series of industrial seminars is conducted in which industrial speakers outline opportunities in particular industries and the various positions within the companies.

In addition to assisting in the placement of graduating students, it also assists industry in the difficult job of locating trained and experienced personnel. The office also assists Alumni to establish new connections.

The Placement Office, of course, cannot give any graduate a guarantee of employment; however, during the past year the Placement Bureau listed several jobs for every graduate and practically all seniors were placed before Commencement. No official part-time placement program is in operation because of the heavy academic schedule.

COOPERATIVE PLAN

Massachusetts Institute of Technology—Lowell Technological Institute

A cooperative arrangement between Lowell Technological Institute and Massachusetts Institute of Technology includes the following major provisions:

(1) The mutual use of the manufacturing and research facilities for graduate and undergraduate theses;

(2) The mutual use of textile libraries of both institutions;

(3) The opportunity for students at each institute to supplement their work by taking work presented at the other institute, and summer programs of instruction;

(4) The formation of joint seminars and the interchange of staff members for special lectures;

(5) Frequent student visits and joint meetings of student societies.

SPECIAL SERVICES OF L.T.I. TO INDUSTRY AND THE COMMUNITY

In addition to the services rendered by the Evening Division, the Alumni Memorial Library, the Research Foundation, and the Summer School program, the college provides such special services to industry and to the community as the following:

Industrial seminars, conferences, and radio programs;

Guidance work in the high schools;

Consultive opportunities with the Faculty;

Collaboration with the Foreign Operations Administration of the Government by showing foreign visitors facilities and by counsel;

Special radio and television programs;

Participation in state-wide and nation-wide exhibits and programs and in community projects.

For information relative to these programs, address The Coordinator of Special Services, Lowell Technological Institute, 1 Textile Avenue, Lowell, Massachusetts.

SUMMER SESSION

The Summer Session is designed primarily to serve three principal areas of interest: Professional Advancement Courses for industrial personnel and home economists; Undergraduate Credit Courses for college students with course deficiencies; and Pre-College Refresher Courses for incoming freshmen at L.T.I.

The industry-sponsored professional advancement program comprises a series of specialized, intensive, one- to three-week courses in textile, paper, and leather technology. The six-week undergraduate credit program stresses fundamental courses in college mathematics, physics, chemistry, English, and economics.

Pre-College Refresher Courses

The pre-college refresher program is especially designed to articulate the high-school training of prospective L.T.I. students with the more intensive college-level studies in basic mathematics, physics, chemistry, and English. The non-credit refresher courses are offered both in a six-week and a four-week session in order to provide adequate coverage for a number of minor deficiencies in the high-school background.

For further information on the Summer Session, write to Professor Ernest P. James, Director of Summer School.

EVENING DIVISION

The Evening Division offers a wide variety of courses in engineering, chemistry, textiles, rubber, paper, leather, electronics, plastics, the social sciences, and art. These courses are designed to fit the needs of the community, particularly those people engaged in industry who wish to further their education.

The Evening Division offers four-year associate degree courses in electrical, electronic, industrial, and mechanical engineering, also five-year associate degree courses in paper, leather, plastics, and rubber engineering.

Two semesters of 15 weeks each are offered, starting late in September and late in January. For further information concerning the Evening Division, write to the Director of the Evening Division.

THE GRADUATE SCHOOL

By act of the General Court of 1935, authority was given to Lowell Technological Institute to confer degrees of Master of Science in Textile Chemistry, Master of Science in Textile Engineering, and Master of Science in Textile Technology to graduate students who satisfactorily complete a program of advanced standing. Recently, authority has been granted to include Master of Science work in Paper Engineering, Electronic Engineering, Leather Engineering, and Chemistry, which will lead to corresponding degrees.

The graduate programs of study offered by the Institute provide for advanced specialized training required by technologists who contribute to industrial progress and human welfare through the application of scientific and engineering principles to existing industrial and human problems. The courses of study allow the graduate of the Institute or of other colleges training men in textile, paper, or leather technology to broaden his knowledge and skills in these areas and to develop a sound research approach to problems in the basic sciences, the development of new products, and industrial production.

Inquiries concerning graduate studies should be addressed to the Director of the Graduate School.

I. Admission to the Graduate School

A. *General Admission*

To be eligible for admission to the Graduate School, an applicant must have received a Bachelor's degree in an acceptable four-year course in which he has maintained a uniformly high scholastic rating. Both quality and quantity of the previous training will be considered. Selection of those applicants admitted will be based as far as possible on their ability to pursue graduate work of high quality.

B. *Special Student Status*

An applicant who meets the general admission requirements, but who wishes to concentrate on certain subjects in specialized techniques, or in some cases on special research programs, may request to be considered for Special Student Status. This work does not lead to a degree.

Acceptance as a special student is contingent upon the consent of the instructor in charge of each subject to which admission is desired.

C. *As a Provisional Graduate Student*

An applicant for admission to the Graduate School who is unable to meet all the requirements specified in (A) may be accepted provisionally, if he satisfies the department in which he wishes to enroll that he is probably able to pursue graduate studies successfully.

The status of such a student will be changed to that of a graduate student upon demonstration of his ability to pursue graduate studies successfully as measured by the completion of his first semester's work with an average rating of at least 2.5 (80%).

D. *Application Procedure*

Those wishing to carry on graduate studies at this Institute should file application with the Director of the Graduate School. Applications may be obtained from the Office of the Graduate School.

Applications for admission should be complete and accurate and must be received not later than the first of June preceding the fall term in which the applicant wishes to enroll. Applications must be supported by letters from at least two persons qualified to judge the ability of the applicant to carry on graduate work and research. The letters should be sent directly from these persons to the Graduate School.

Transcripts of all undergraduate records (and graduate, if any) must be sent directly to the Office of the Graduate School by the institutions which the applicant has previously attended. All transcripts must be official, with appropriate seals and signatures. Records, descriptions of subjects, and letters must be in English. Each subject must be described in terms of content, scope, number of hours per week, and number of weeks duration. Lecture and laboratory time should be properly distinguished. If a catalogue giving such descriptions in English is available, the subjects taken may be clearly marked in a copy sent to the Graduate School.

A reading and speaking knowledge of English is necessary for an applicant to be considered for acceptance. Most of the subjects are presented in lecture form, making it difficult for those who do not have a reasonably fluent command of the English language.

Except in unusual circumstances, applications will be acted upon and the applicant notified of the decision by July 1. Foreign

applicants are urged to make application as early as possible so as to leave enough time for visa and other arrangements to be made.

II. Graduate Courses Offered

Graduate programs leading to the Master of Science degree are offered in the fields of chemistry, textile chemistry, textile engineering, paper engineering, and electronic engineering.

Because of the varied objectives of the graduate student, the course of study is arrived at through consultation with the student's graduate adviser.

Subjects numbered 500 and above are offered for graduate credit. A limited number of undergraduate subjects are available for graduate credit. The choice of these undergraduate subjects with graduate credit is subject to the approval of the Department Head.

Each program will include an original thesis.

TEXTILE CHEMISTRY

Graduate work in Textile Chemistry allows qualified students the opportunity to pursue advanced study in the physical chemistry of textile processing such as dyeing, wet finishing and fiber modification. Studies on the organic chemistry of dyes may also be undertaken.

Recent studies have been on the theories of dyeing of natural and synthetic fibers and the application of synthetic finishes.

Such studies are carried out by graduate class work, seminars, and original theses.

The following subjects must be included in the student's program:

First Semester:

CH 503 Interpretation of Data
CH 505 Physical Chemistry of Dyeing
CH 555 Textile Chemistry Seminar

Second Semester:

CH 512 Physical Chemistry of Surface-Active Agents
CH 516 Chemical Thermodynamics
CH 556 Textile Chemistry Seminar

Other subjects of an advanced nature are to be elected, subject to the approval of the Graduate Adviser in Textile Chemistry and of the Chairman of the Chemistry Division.

CHEMISTRY

This program has been developed to provide opportunity for advanced study and research training in chemistry. Chemistry subjects include both general and specialized fields of study. Provision is also made for the student to elect certain advanced courses in related fields of mathematics, physics, and engineering.

Subject Requirements—Of the 20 credit minimum, exclusive of thesis, required in listed courses (see Requirements for Graduation at the end of this section), 15 credits must be taken in chemistry. Recommended courses include: CH 503, CH 523-4, CH 525-6, CH 423, CH 424, CH 425, CH 431-2, CH 443-4, CH 446. All students must take Chemistry Seminar (CH 507-8). The remaining credits (five or more) may be taken either in chemistry or in such related fields as engineering, physics, and mathematics. Credit in these elective courses is given only if subjects are above the sophomore level and if they are approved by the Director of the Graduate School and the Chairman of the Chemistry Division.

Language Requirements—For the degree of Master of Science in Chemistry, the student must demonstrate his ability to read technical German.

Advisory Committee—The development of the student's program of study shall be the responsibility of an Advisory Committee consisting of three members from the faculty of the Division of Chemistry. This committee shall be appointed by the Director of the Graduate School upon the recommendation of the Division Chairman and shall include the thesis supervisor.

Thesis Examination—Each candidate for a Master of Science degree in Chemistry, upon completion of his thesis, shall present himself for an oral examination in the field of his thesis to an Examination Committee appointed by the Director of the Graduate School and consisting of his Advisory Committee and any additional faculty members considered desirable by the Director. While only members of the Examination Committee and the Director of the Graduate School may conduct the examination, all faculty members may attend. The examination shall be held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Application to take the examination must be filed by the student with the Director of the Graduate School at least one month prior to the close of the last semester. Each student has the right to one re-examination within a period of one year.

TEXTILE ENGINEERING

Graduate work in Textile Engineering is offered so that qualified students who have completed one of the courses in Textile Engineering at Lowell Technological Institute may undertake advanced studies concerning the physical properties of textile materials and modern methods of evaluating them.

Opportunity is also provided for engineering graduates of other colleges to secure fundamental knowledge of textile materials and processing which is a co-requisite for graduate study and research in Textile Engineering.

For graduate subjects in Textile Engineering consult subject descriptions under Engineering, Mathematics, and Physics.

PAPER ENGINEERING

The graduate program in Paper Engineering is for the purpose of giving advanced work in papermaking, paper converting or allied fields.

The Paper Engineering Department will consider graduate students from three different sources:

(a) Graduates of the Lowell Technological Institute B.S. Paper Engineering course;

(b) Paper Engineering B.S. and M.S. graduates of other schools;

(c) General B.S. and M.S. engineering graduates with no previous paper training.

Students with the backgrounds given under (a) and (b) should be able to complete the work in one academic year. Students in group (c) should be able to complete the degree requirements in two academic years.

A graduate student in Paper Engineering will take approximately 50% of his graduate subjects (including thesis) in the Paper Engineering Department. The balance may be taken as electives related to the paper field and approved by the Department.

The graduate subjects offered in this Department are:

PA 501-502	Graduate Thesis
PA 503-504	Plant Design
PA 505-506	Advanced Papermaking and Paper Converting
PA 507-508	Graduate Seminar

ELECTRONIC ENGINEERING

A graduate program in Electronic Engineering will be initiated in 1957-58 on a limited basis. This program will be restricted this year to

(a) graduates of the Lowell Technological Institute with a B.S. degree in Electronic Engineering, and

(b) qualified employees of neighboring industrial organizations which are participating in this graduate program.

III. Term of Residence

Applicants with a sufficient background in their chosen field of concentration will normally require one academic year of residence to complete the requirements for the Master's degree. Those with no background will require a minimum of two years of residence.

Graduates of other colleges usually need more than one academic year to fulfill the degree requirements, even though they majored as undergraduates in their graduate field of specialization.

IV. Expenses

Tuition, fees, and other expenses for graduate students are for the most part the same as given on page 33 for undergraduate students.

Thesis-Binding Fee

All graduate students are required to pay for the expense of binding the original thesis which will be retained in the Institute Library. Certain departments will also require a bound copy of the thesis to be deposited in the department's library.

Both of these expenses must be paid at the Library prior to registering for the thesis work. The receipt obtained from the Library will allow the student to register for the subject.

V. Candidacy for a Master's Degree

Admission to the Graduate School does not indicate that the student is a candidate for the Master's degree. A student enrolled in a graduate degree program, who has established an acceptable scholarship record and has completed half of the required program, may make application to the Director of the Graduate School to become a candidate for the degree.

Application for approval of candidacy for the advanced degree must be filed after completion of one-half of the required program and not later than twelve weeks prior to the date on which the degree is to be conferred.

VI. Requirements for Graduation

To be recommended for the Master of Science degree a candidate must have

(a) Completed a course of study approved by the department in which he has been enrolled. The approved course of study is to have a minimum of 30 credit hours, including thesis. A minimum of 20 credit hours is to be spent in listed subjects, and the program should have no fewer than 5 credit hours of thesis work.

(b) Completed a thesis (original research or other investigation, optional with department) approved by the department in which he has been enrolled, and successfully passed any oral or written examinations on his thesis required by the department at the time his thesis is submitted for final approval.

(c) Maintained residence for at least one academic year.

(d) Maintained an average rating of B in graduate subjects and passed all undergraduate subjects submitted for graduate credit with a grade of B or better.

UNDERGRADUATE PROGRAMS OF STUDY

Eleven fields of study are open to undergraduates. All are four years in length and lead to the degree of Bachelor of Science. These fields are:

Chemistry

Electronic Engineering

General Engineering

Leather Engineering

Paper Engineering

Plastics Engineering

Textile Chemistry

Textile Engineering—Engineering Option

Textile Engineering—General Manufacturing Option

Textile Sales and Management

Textile Technology

These curricula are outlined in the following pages. They are under constant study and subject to revision whenever changes are necessary to enable the Institute better to fulfill its mission of service to Industry.

In all courses considerable work in practical industrial applications has been included in addition to the fundamental studies in the physical sciences, mathematics, and engineering. Classes in the humanities and social sciences have been woven into all curricula in a conscious effort to produce graduates not only with a thorough technical training but also with the broad cultural background which marks the educated man.

THE FRESHMAN PROGRAM

Orientation

The first week's program in the fall for entering freshmen is called Freshman Week. It is devoted to facilitating the adjustment of the new student to his physical and social surroundings. Under the sponsorship of the Office of the Dean of Students, a program of meetings, lectures and conferences will be presented in order to acquaint the entering class with the traditions, customs, rules and regulations, courses of instruction, organizations, recreational activities and other facilities of Lowell Technological Institute.

All new students are required to attend the program of Freshman Orientation which carries no academic credits but is designed to make the freshman aware of his new responsibilities and to help him adjust himself to college life. It guides him in making the most efficient use of his time and talents, attempts to develop his ability to think for himself and react thoughtfully and intelligently to new ideas and viewpoints.

Freshman Course of Study

First Semester

*AS	101	Air Science	(2-1)2
CH	101	General Chemistry	(4-2)4
EN	113	Engineering Graphics	(0-3)1
GS	111	English Composition and Reading	(3-0)3
†MA	107	Introduction to Mathematical Analysis	(4-0)4
PH	103	Physics	(4-1)3
		Total credit hours	17

Second Semester

*AS	102	Air Science	(2-1)2
CH	102	General Chemistry	(4-2)4
EN	114	Engineering Graphics	(0-3)1
GS	112	English Composition and Reading	(3-0)3
MA	108	Calculus and Analytic Geometry	(5-0)5
PH	104	Physics	(4-1)4
		Total credit hours	19

In addition to the preceding schedule all nonveteran men students who are physically qualified must take physical education for the whole freshman year. This subject meets one hour per week for AFROTC students and two hours per week for all others. It carries no academic credit.

*Required of all able-bodied, nonveteran male citizens (see page 49). Other students must take in its place GS 101-102, World Economic Geography.

†Freshmen entering in September, 1957, without credit for trigonometry must also take MA A, Plane Trigonometry and Logarithms.

The Elective System

In all curricula an opportunity is afforded the student to elect subjects in addition to those required for graduation. These electives fall into two categories: technical electives and general electives.

Technical electives give the student a chance to broaden his professional knowledge by taking subjects allied to his main interest or to further his knowledge of a particular phase by taking additional work therein.

General electives are subjects offered by the Division of General Studies. They include cultural courses in the humanities or social sciences, or management courses to help fit the graduate for positions of executive responsibility. Normally all general electives taken by a student as an undergraduate must be chosen from one of the five cores listed below. However, in particular cases and with the division chairman's permission elective work may be divided between two cores.

I. Management Core

GS 301	Economic Development of the United States	(3-0)3
GS 302	Modern Labor Problems	(3-0)3
GS 461	Personnel Management	(3-0)3
GS 463	Business Law	(3-0)3
GS 465	Management Problems	(3-0)3

II. Finance Core

GS 313	Money and Banking	(3-0)3
GS 341	Accounting – I	(3-0)3
GS 342	Accounting – II	(3-0)3
GS 468	Business Finance	(2-0)2
Elective		(3-0)3

III. Sales Core

GS 321	Marketing Principles and Problems	(3-0)3
GS 322	Marketing Principles and Problems	(3-0)3
GS 442	Foreign Trade	(3-0)3
GS 443	Advertising Principles and Problems	(3-0)3
Elective		(3-0)3

IV. Literature Core

GS 222	Appreciation of Literature	(3-0)3
GS 232	Comparative Literature	(3-0)3
GS 473	Modern Drama	(3-0)3
GS 475	The Modern American Novel	(3-0)3
Elective		(3-0)3

V. History and Government Core

GS 223	The United States since 1865	(3-0)3
GS 226	World History since 1900	(3-0)3
GS 301	Economic Development of the United States	(3-0)3
GS 469	Comparative Modern Governments	(3-0)3
GS 471	American Foreign Policy, 1774 to the Present	(3-0)3

Chemistry

The first two years are common in Chemistry and Textile Chemistry. At the beginning of the junior year, students select their major program. Those who elect to continue in Chemistry are provided with a basic knowledge of the four major branches of chemistry, inorganic, organic, analytical, and physical, and with advanced instruction in one or more of the same areas. Subjects in the humanities and social sciences are included as a recognized essential part of the student's educational program, and a broad elective system permits the student to select advanced courses in engineering, mathematics, and physics.

This curriculum prepares the student either for a position in the chemical industry or for further training at the graduate level. Those students planning for a career in chemical research are advised to consider graduate work beyond the baccalaureate degree.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201M	Organic Chemistry	(3-6)5
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202M	Organic Chemistry	(3-6)5
CH	206	Qualitative Analysis	(2-6)4
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)3
		Total credit hours	18

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	307	Atomic and Molecular Structure	(3-0)3
CH	331M	Physical Chemistry	(3-3)4
GS	201	Economics	(3-0)3
GS	261	Technical German	(3-0)3
AS	301	Air Science, or General Elective	2 to 4
		Technical Elective	3
		Total credit hours	18 to 20

Second Semester

CH	314	Advanced Quantitative Analysis	(2-4)3
CH	332	Physical Chemistry	(3-3)4
GS	202	Economics	(3-0)3
GS	262	Technical German	(3-0)3
AS	302	Air Science, or General Elective	2 to 4
		Technical Elective	3
		Total credit hours	18 to 20

SENIOR YEAR

First Semester

CH	423 or 431 or 443	Advanced Chemistry	(3-0)3
AS	401	Air Science, and one General Elective; or two General Electives	6 or 7
		Technical Electives	6
		Total credit hours	15 or 16

Second Semester

CH	424 or 432 or 444	Advanced Chemistry	(3-0)3
AS	402	Air Science, and one General Elective; or two General Electives	6 or 7
		Technical Electives	6
		Total credit hours	15 or 16

Recommended Technical Electives for juniors and seniors: CH 333, 334, 342, 352, 403-404, 446, 481 or 482; PH 302, 322, and 504; for seniors only: CH 408-409, 423, 424, 431-432, and 443-444.

Recommended General Electives: GS 222, 223, 226, 232, 301, 302, 303, 469 or 470, 471 or 472, 473, and 475.

NOTE: For explanation of the Elective System, see page 65.

Electronic Engineering

The objective of the curriculum in Electronic Engineering is to provide the student with a sound foundation for a professional career in electronics. Toward this end he is given a thorough grounding in electronic science and engineering together with an intensive training in mathematics and physics.

In all courses in electronics and physics the techniques of experimental science and technology are emphasized by investigative work in the laboratory and lecture demonstrations in the classroom.

Studies in the humanities and social sciences form an important part of the program since these subjects broaden the student's outlook. They also serve to focus attention on the importance of nontechnical knowledge in determining the student's ultimate level of responsibility in professional life. Emphasis is placed on the development of the student's ability to speak and write effectively so that he can express his thoughts and the results of his experimental investigations with clarity.

In addition to his formal studies, the student is encouraged and expected to do independent reading in philosophy, history, and literature, as well as supplementary work in the areas of his special technical interest.

During each semester of the undergraduate program in Electronic Engineering a case study is made of some novel topic or situation occurring in industry or in the course of an engineer's professional work. This gives the student an opportunity to develop his ability to make reasoned judgments in complex situations wherein nontechnical factors frequently are of paramount importance.

Due to limitations of staff and facilities, only a limited number of students can be accepted in Electronic Engineering. Such acceptance is based upon the student's performance in mathematics and physics during the freshman year.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EL	201	Introductory Circuit Theory	(4-0)4
EL	203	Elementary Electricity and Magnetism Laboratory	(0-3)1
EL	205	Introductory Field Theory	(4-0)4
EL	207	Intermediate Engineering Mathematics	(4-0)4
GS	213	Communication of Ideas	(3-0)3
		Total credit hours	18

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EL	202	Introductory Circuit Theory	(4-0)4
EL	204	Elementary Electricity and Magnetism Laboratory	(0-3)1
EL	206	Introductory Field Theory	(4-0)4
EL	208	Differential Equations for Engineers	(4-0)4
EN	212	Machine Tool Laboratory	(1-2)1
GS	214	Technical and Scientific Writing	(3-0)3
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

EL	301	Introduction to Physical Electronics	(3-0)3
EL	303	Electronic Circuits	(3-0)3
EL	305	Electronics Laboratory	(0-4)2
EL	307	Electromagnetic Devices and Machinery	(3-0)3
EL	311	Engineering Mathematics	(4-0)4
AS	301	Air Science, or General Elective	3 or 4
		Total credit hours	18 or 19

Second Semester

EL	304	Electronic Circuits	(3-0)3
EL	306	Electronics Laboratory	(0-4)2
EL	308	Electromagnetic Devices and Machinery	(3-0)3
EL	310	Electromagnetics	(3-0)3
EL	312	Engineering Mathematics	(4-0)4
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	18 or 19

SENIOR YEAR

First Semester

EL	401	Servomechanisms	(3-0)3
EL	411	Applied Electronics Laboratory	(0-4)2
EL	413	Thermodynamics and Properties of Materials	(3-0)3
AS	401	Air Science, and one Technical Elective; or two Technical Electives	6 or 7
		Total credit hours	14 or 15

Technical Electives

EL	403	Microwave Electronics	(3-0)3
EL	409	Electronic Projects Laboratory	(0-4)2
EL	415	Communications Theory	(3-0)3
EL	417	Network Analysis	(3-0)3
EL	419	Basic Principles of Computers	(3-0)3

Second Semester

EL	402	Servomechanisms	(3-0)3
EL	412	Applied Electronics Laboratory	(0-4)2
EL	414	Thermodynamics and Properties of Materials	(3-0)3
AS	402	Air Science, and one Technical Elective; or two Technical Electives	6 or 7
		Total credit hours	14 or 15

Technical Electives

EL	404	Microwave Electronics	(3-0)3
EL	410	Electronic Projects Laboratory	(0-4)2
EL	416	Communications Theory	(3-0)3
EL	418	Network Analysis	(3-0)3
EL	420	Instrumentation	(3-0)3

NOTE: For explanation of the Elective System, see page 65.

General Engineering

In General Engineering the student may obtain the broad fundamental training in engineering and science which is demanded by modern industry. There is a rapidly growing need in modern industry for men who are versatile in their engineering capabilities, soundly trained in the fundamentals which underlie all engineering, and therefore adaptable to assignment to numerous positions in the industrial organizations of today. The curriculum, cutting across those of the conventional engineering courses, is designed to give the student a fundamental preparation for a wide variety of positions in industry. Through a suitable offering of electives in the senior year, provision is made for those students who acquire an interest in a particular career or industry.

During the first two years of the course, basic training is given in the sciences of chemistry, mathematics and physics. In the third and fourth years, engineering subjects such as applied mechanics, electronics, electrical machinery, thermodynamics, machine design, and fluid mechanics will further develop the analytical mind, the ability to solve engineering problems, and the latent capacity for creative design. Subjects in the fields of the humanities and the social sciences are included in the curriculum so that the engineer may be prepared for a position of executive responsibility.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	203	Mechanism	(3-0)3
EN	207	Machine Drawing	(0-6)2
EN	211	Machine Tool Laboratory	(1-2)1
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	18

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	222	Applied Mechanics I	(3-0)3
EN	232	Engineering Materials	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)3
		General Elective	(3-0)3
		Total credit hours	17

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	301	Applied Mechanics II	(3-0)3
EN	303	Electrical Circuits	(3-2)3
EN	305	Thermodynamics	(3-0)3
GS	201	Economics	(3-0)3
AS	301	Air Science, and one Technical Elective; or two Technical Electives	6 to 8
		Total credit hours	18 to 20

Technical Electives

CH	331	Physical Chemistry	(3-1½)4
EN	307	Surveying and Structures	(3-3)4
EN	309	Machine Tool Fundamentals	(2-2)3
EN	313	Advanced Mechanism	(2-2)3
MA	301	Advanced Calculus	(3-0)3

Second Semester

EN	302	Applied Mechanics III	(3-0)3
EN	316	Heat Engineering	(3-2)4
PH	322	Electronics	(3-2)4
AS	302	Air Science, and one Technical Elective; or one General and one Technical Elective	6 to 8
		Total credit hours	17 to 19

Technical Electives

CH 332	Physical Chemistry	(3-3)4
CH 352	Chemical Engineering	(3-0)3
EN 308	Structures	(3-0)3
MA 302	Advanced Calculus	(3-0)3

SENIOR YEAR

First Semester

EN 351	Statistical Methods	(3-0)3
EN 401	Principles of Electrical Engineering	(3-2)4
GS 209	Speech	(2-0)2
GS 211	Business English	(2-0)2
AS 401	Air Science, and one Elective; or two Electives	6 or 7
	Total credit hours	17 or 18

Electives

CH 441	Chemical Engineering	(3-0)3
EN 411	Advanced Heat Engineering	(3-2)4
EN 427	Machine Design	(2-3)3
EN 433	Manufacturing Tools and Methods	(3-0)3
GS 341	Accounting—I	(3-0)3
PH 401	Textile Microscopy	(2-3)3
PH 503	Spectrographic Methods	(2-2)3
PH 505	X-Ray Diffraction	(2-3)3

Second Semester

EN 406	Fluid Mechanics	(3-2)4
EN 420	Industrial Instrumentation	(2-3)3
GS 412	Industrial Management	(3-0)3
AS 402	Air Science, and/or Electives	7 or 8
	Total credit hours	17 or 18

Electives

EN 402	Electrical Control Systems	(3-2)4
EN 404	Heat Transfer	(2-0)2
EN 428	Machine Design	(2-3)3
EN 504	Air Conditioning	(2-2)2
PH 504	Spectrographic Methods	(2-2)3
PH 508	Electron Microscopy	(1-3)2

NOTE: For explanation of the Elective System, see page 65.

Leather Engineering

The concept of a leather engineer is new to the leather industry. The economics, size, and scope of this industry warrant the careful training of individuals capable of handling its specific problems.

The leather industry realizes that many of its products can be improved by the application of sound and intelligent research and development. There is a constantly increasing demand for engineers with a thorough understanding of the art of leather manufacturing.

In this curriculum, emphasis is placed on the fundamentals of engineering including mathematics, physics, chemistry, and theoretical and applied mechanics. These subjects are basic in any sound undergraduate program. To these are added subjects in the application of basic scientific principles to leather technology.

In order properly to balance this program, subjects in general education are offered, since the engineer must be trained to be a leader not only in his profession but also in everyday economic, social and political affairs. He must also be trained to meet success, promotion, and the challenge of directing the work of others.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	205	Qualitative Analysis	(2-6)4
EN	325	Applied Mechanics	(3-0)3
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		Total credit hours	20

*Alternate:

GS	201	Economics	(3-0)3

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	212	Quantitative Analysis	(3-6)5
LE	202	Applied Leather Analysis	(1-4)2
PH	206	Physics	(3-2)3
		General Elective	(3-0)3
		Total credit hours	19

Alternate:

GS	202	Economics	(3-0)3

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-1½)4
LE	301	Leather Technology	(3-6)5
LE	303	Leather Histology	(2-4)4
AS	301	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	19 or 20

Second Semester

CH	332	Physical Chemistry	(3-3)4
LE	302	Leather Technology	(3-6)5
LE	304	Advanced Leather Histology	(2-4)4
AS	302	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

EN	351	Statistical Methods	(3-0)3
LE	401	Leather Technology	(3-6)5
LE	405	Leather Seminar	(1-0)1
PH	321	Electronics	(3-1)3
AS	401	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	18 or 19

Second Semester

EN	344	Electrical Machinery	(3-2)4
LE	402	Leather Technology	(3-6)5
LE	404	Properties of Leather	(2-3)3
LE	406	Leather Seminar	(1-0)1
AS	402	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	19 or 20

NOTE: For explanation of the Elective System, see page 65.

Paper Engineering

The object of this course is to fit a man for work in the papermaking, paper-converting, or allied industries. For this, a thorough training in basic chemical engineering is offered, accompanied by instruction in the theory and practice of pulp and paper manufacture and paper converting.

Paper engineering involves the application of cellulose and plastics chemistry together with engineering principles to the handling of the material in the web or sheet form, as it is treated, coated, or converted into the final product. Every effort is made by cooperation with local concerns to supplement college work by experience in actual manufacturing conditions, thus giving the student an opportunity to familiarize himself with equipment commonly in use in the industry.

Students taking this course should be well equipped for work in the papermaking or paper-converting fields, or for graduate study in paper technology.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		Total credit hours	18

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	290	Introduction to Chemical Engineering	(3-3)4
EN	326	Applied Mechanics	(3-0)3
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)3
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-1½)4
CH	333	Industrial Stoichiometry	(3-0)3
PA	301	Pulp Technology	(3-0)3
PA	303	Pulp Laboratory	(2-6)4
PH	321	Electronics	(3-1)3
AS	301	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	334	General Colloid Chemistry	(3-0)3
CH	352	Chemical Engineering	(3-0)3
PA	302	Paper Technology	(3-0)3
PA	304	Paper Laboratory	(2-6)4
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

SENIOR YEAR

First Semester

CH	441	Chemical Engineering	(3-0)3
PA	403	Converting Technology	(3-0)3
PA	405	Converting Laboratory	(2-6)4
PA	409	Mill Inspections	(1-4)2
AS	401	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	18 or 19

Second Semester

CH	442	Chemical Engineering Thermodynamics	(3-0)3
EN	344	Electrical Machinery	(3-2)4
EN	352	Statistical Methods	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
PA	414	Paper Problems	(2-6)4
AS	402	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

NOTE: For explanation of the Elective System, see page 65.

Plastics Engineering

This curriculum has as its objective the training of engineers specifically prepared to cope with the many technical and production problems found in the rapidly expanding field of plastics fabrication.

The emphasis is on the engineering principles involved in the fabrication of plastic materials into useful forms rather than the chemistry involved in the manufacture of the plastic material itself. Due to the close relationship involved between the physical and chemical properties of such materials, however, the curriculum involves considerably more chemistry than most engineering courses.

A basic training in mathematics and physics is required as well as elementary and advanced engineering subjects. In the third and fourth years this basic knowledge is focused on the problems of the plastics industry, including design, manufacture and testing.

Classes in the humanities and applied economics round out the education of the plastics engineer and equip him to advance to the administrative as well as the purely technological type of position.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	205	Qualitative Analysis	(2-6)4
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		Total credit hours	17

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	212	Quantitative Analysis	(3-6)5
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)3
		Total credit hours	17

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	331M	Physical Chemistry	(3-3)4
EN	211	Machine Tool Laboratory	(1-2)1
EN	325	Applied Mechanics	(3-0)3
EN	405	Electronic Controls and Power Circuits	(3-2)4
PL	301	Introduction to Plastics Technology	(3-3)4
AS	301	Air Science, or GS 201, Economics	3 or 4
		Total credit hours	19 or 20

Second Semester

CH	332	Physical Chemistry	(3-3)4
EN	232	Engineering Materials	(3-0)3
EN	234	Plastics Mold Design and Construction	(1-2)1
EN	332	Strength of Materials	(3-0)3
PL	302	Introduction to Plastics Technology	(3-3)4
AS	302	Air Science, or GS 202, Economics	3 or 4
		Total credit hours	18 or 19

SENIOR YEAR

First Semester

CH	403	Chemistry of High Polymers	(3-3)4
PL	401	Advanced Plastics Technology	(2-3)3
PL	403	Properties of Polymers	(2-3)3
PL	411	Plastics Seminar	(1-0)1
AS	401	Air Science, and one Elective; or two Electives	6 or 7
		Total credit hours	17 or 18

Second Semester

CH	404	Chemistry of High Polymers	(3-3)4
EN	408	Fluid Mechanics	(3-0)3
EN	422	Industrial Instrumentation	(2-0)2
PL	402	Advanced Plastics Technology	(2-3)3
PL	404	Properties of Polymers	(2-3)3
PL	412	Plastics Seminar	(1-0)1
AS	402	Air Science, or one Elective	3 or 4
		Total credit hours	19 or 20

Electives

CH	307	Atomic and Molecular Structure		(3-0)3
CH	423	Advanced Organic Chemistry I		(3-0)3
CH	424	Advanced Organic Chemistry II		(3-0)3
EN	203	Mechanism		(3-0)3
EN	502	Statistical Quality Control		(3-0)3
EN	509 or 510	Advanced Statistical Methods		(3-0)3
GS	261 - 262	Technical German	(3-0)	(3-0)6
MA	206	Differential Equations		(3-0)3

NOTE: For explanation of the Elective System, see page 65.

Textile Chemistry

A sound foundation in basic chemistry and a knowledge of chemical applications in textiles and in textile processes are combined in this course to provide a specialized training for chemists wishing to work in the textile industry or in related chemical industries producing auxiliary chemicals and fibers.

The basic purpose of this curriculum is to prepare students for a professional life in chemistry, and most graduates enter the chemical industry in positions where substantial use is made of their specialized training. Both the chemical and textile industries have great need of textile chemists, and each year representatives from industry return to the Lowell Technological Institute in search of majors in this field to fill positions wherein a knowledge of textiles is necessary for the solution of problems in research and development which deal both directly and indirectly with textiles.

Textile chemistry majors have a common curriculum in the fundamentals of chemistry, mathematics, and physics through the first two years with chemistry majors, and select the textile chemistry course at the beginning of the junior year. Subjects are included in the humanities and social sciences as a recognized essential part of the educational program.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201M	Organic Chemistry	(3-6)5
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202M	Organic Chemistry	(3-6)5
CH	206	Qualitative Analysis	(2-6)4
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)3
		Total credit hours	18

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	311	Textile Quantitative Analysis	(2-4)3
CH	331M	Physical Chemistry	(3-3)4
†CH	355	Chemistry and Physics of Fibers	(2-3)3
GS	201	Economics	(3-0)3
TE	327	Elements of Textile Manufacture	(2-2)3
AS	301	Air Science, or General Elective	2 to 4
		Total credit hours	18 to 20

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	356	Chemistry of Fiber Purification	(2-3)3
CH	364	Textile Colloid Chemistry	(4-0)4
GS	202	Economics	(3-0)3
TE	328	Elements of Textile Manufacture	(2-2)3
AS	302	Air Science, or General Elective	2 to 4
		Total credit hours	19 to 21

†Class of 1959 should substitute EN 351, Statistical Methods, for CH 355.

SENIOR YEAR

First Semester

*CH	425	Organic Chemistry of Colored Substances	(2-0)2
CH	453	Theory of Dyeing	(3-4)4
TE	403	Textile Evaluation	(2-2)3
TE	445	Textile Finishing	(4-2)4
AS	401	Air Science, or Electives	6 or 7
		Total credit hours	19 or 20

Second Semester

CH	422	Chemical Textile Testing	(2-3)3
CH	454	Industrial Dyeing and Printing	(2-8)4
TE	446	Textile Finishing	(2-4)4
AS	402	Air Science, or Electives	6 or 7
		Total credit hours	17 or 18

*Class of 1958 should substitute a General Elective for this subject.

Recommended technical electives are: CH 333, 334, 342, 352, 403-404, 408-409, 423, 424, 431-432, 443-444, 446, 481; MA 206; PH 302, 322, 504.

NOTE: For explanation of the Elective System, see page 65.

Textile Engineering

Engineering Option

A textile engineer is defined as one who has had a basic training in engineering to which has been added a knowledge of the manufacture of textiles, their properties and uses.

The Engineering Option of Textile Engineering provides a training in mechanical engineering similar to that found in other engineering schools. To this is added a knowledge of textiles sufficient to prepare the individual for positions in the textile and allied industries which may involve research and engineering principles. Business subjects and the humanities are included in the curriculum so that this type of textile engineer may have the educational potential to rise to a position of executive responsibility.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	203	Mechanism	(3-0)3
EN	207	Machine Drawing	(0-6)2
EN	211	Machine Tool Laboratory	(1-2)1
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	18

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	222	Applied Mechanics I	(3-0)3
EN	232	Engineering Materials	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)3
		General Elective	(3-0)3
		Total credit hours	17

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	301	Applied Mechanics II	(3-0)3
EN	305	Thermodynamics	(3-0)3
EN	351	Statistical Methods	(3-0)3
PH	321	Electronics	(3-1)3
TE	327	Elements of Textile Manufacture	(2-2)3
AS	301	Air Science, or GS 201, Economics	3 or 4
		Total credit hours	18 or 19

Second Semester

EN	302	Applied Mechanics III	(3-0)3
EN	342	Principles of Electrical Engineering	(3-2)4
EN	410	Principles of Heat Engineering	(3-2)4
TE	328	Elements of Textile Manufacture	(2-2)3
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	17 or 18

SENIOR YEAR

First Semester

EN	401	Principles of Electrical Engineering	(3-2)4
EN	431	Advanced Physical Textile Testing	(2-3)3
GS	209	Speech	(2-0)2
GS	211	Business English	(2-0)2
GS	341	Accounting—I	(3-0)3
AS	401	Air Science, or General Elective	3 or 4
		Technical Elective	3
		Total credit hours	20 or 21

Technical Electives

EN	427	Machine Design	(2-3)3
EN	433	Manufacturing Tools and Methods	(3-0)3
PH	401	Textile Microscopy	(2-3)3
PH	503	Spectrographic Methods	(2-2)3
PH	505	X-Ray Diffraction	(2-3)3

Second Semester

EN	408	Fluid Mechanics	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
EN	430	Engineering Design of Textile Structures	(3-0)3
GS	412	Industrial Management	(3-0)3
AS	402	Air Science, or General Elective	3 or 4
		Technical Electives	3 or 4
		Total credit hours	18 to 20

Technical Electives

EN	404	Heat Transfer	(2-0)2
EN	428	Machine Design	(2-3)3
EN	504	Air Conditioning	(2-2)2
PH	402	Textile Physics	(2-2)3
PH	504	Spectrographic Methods	(2-2)3
PH	508	Electron Microscopy	(1-3)2

NOTE: For explanation of the Elective System, see page 65.

Textile Engineering

General Manufacturing Option

It is the belief that except in highly specialized areas, e.g., chemistry, the ideal training for the textile industry combines an understanding of textile processing relating to all fibers with a sound engineering and scientific background, as well as an orientation to society and business through a selected core of liberal arts and economic subjects.

The objective of the General Manufacturing Option is to provide the textile industry with technically trained textile engineers. The curriculum has been planned so that the textile engineer (1) will be given as complete and thorough a knowledge and understanding of the raw materials, machines, and processes peculiar to the manufacture of all fibers as is possible; (2) will have a basic training in engineering and the fundamental sciences; and (3) will acquire a knowledge of business and managerial principles and the social sciences.

The first component should prepare the student to be useful in any textile plant regardless of fiber processed. The second should develop a man who will approach textile problems from an engineering viewpoint, thus contributing toward their solution the benefits of a trained analytical mind. The third objective should aid in the production of a well-rounded individual.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	203	Elementary Organic Chemistry	(3-0)3
EN	201	Machine Drawing	(0-3)1
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
TE	203	Textile Fibers	(4-0)3
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	204	Mechanism	(3-0)3
EN	212	Machine Tool Laboratory	(1-2)1
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)3
TE	206	Yarn Manufacture	(3-3)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	325	Applied Mechanics	(3-0)3
EN	351	Statistical Methods	(3-0)3
PH	321	Electronics	(3-1)3
TE	307	Yarn Manufacture	(3-3)4
TE	309	Fabric Manufacture	(2-2)2
AS	301	Air Science, or General Elective	3 or 4
		Total credit hours	18 or 19

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
EN	332	Strength of Materials	(3-0)3
EN	344	Electrical Machinery	(3-2)4
TE	308	Yarn Manufacture	(3-3)4
TE	310	Fabric Manufacture	(3-3)4
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

SENIOR YEAR

First Semester

EN	403	Principles of Heat Engineering	(3-2)4
GS	341	Accounting—I	(3-0)3
TE	403	Textile Evaluation	(2-2)3
TE	405	Finishing Technology	(4-2)4
AS	401	Air Science, or a Technical Elective; and one General Elective	6 or 7
		Total credit hours	20 or 21

Technical Electives

EN	407	Fluid Mechanics	(3-0)3
TE	407	Knitting	(2-3)3
TE	417	Cotton Mill Organization	(4-0)4

Second Semester

GS	210	Speech	(2-0)2
GS	212	Business English	(2-0)2
GS	412	Industrial Management	(3-0)3
TE	404	Textile Evaluation	(2-2)3
TE	406	Finishing Technology	(0-4)2
AS	402	Air Science, or a Technical Elective; and one General Elective	6 or 7
		Total credit hours	18 or 19

Technical Electives

EN	420	Industrial Instrumentation	(2-3)3
EN	430	Engineering Design of Textile Structures	(3-0)3

NOTE: For explanation of the Elective System, see page 65.

Textile Sales and Management

This course is designed for those interested in the marketing and management phases of the textile and allied industries. Its emphasis is on all three branches of management—production, distribution, and finance.

The student is given a fundamental knowledge of the natural sciences and their application to the processing of all types of textile fibers. This scientific and manufacturing background is increasingly essential to effective merchandising and management, particularly at the higher levels of supervision.

A substantial amount of time is also devoted to cultural subjects designed to broaden the student's outlook, increase his understanding of social and economic problems, and improve his ability to get along with people.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	203	Elementary Organic Chemistry	(3-0)3
GS	201	Economics	(3-0)3
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
TE	203	Textile Fibers	(4-0)3
		Total credit hours	18

*Alternate:

Elective approved by Division Head

Second Semester

*AS	202	Air Science	(2-1)2
EN	352	Statistical Methods	(3-0)3
GS	202	Economics	(3-0)3
GS	206	Man and His Environment	(3-0)3
PH	206	Physics	(3-2)3
TE	206	Yarn Manufacture	(3-3)4
		Total credit hours	18

*Alternate:

Elective approved by Division Head

JUNIOR YEAR

First Semester

GS	311	Economic Statistics	(3-0)3
GS	321	Marketing Principles and Problems	(3-0)3
GS	341	Accounting—I	(3-0)3
TE	307	Yarn Manufacture	(3-3)4
TE	309	Fabric Manufacture	(2-2)2
AS	301	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	18 or 19

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
GS	322	Marketing Principles and Problems	(3-0)3
GS	342	Accounting—II	(3-0)3
TE	308	Yarn Manufacture	(3-3)4
TE	310	Fabric Manufacture	(3-3)4
AS	302	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

GS	303	Psychology	(3-0)3
GS	461	Personnel Management	(3-0)3
GS	463	Business Law	(3-0)3
TE	403	Textile Evaluation	(2-2)3
TE	405	Finishing Technology	(4-2)4
AS	401	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	19 or 20

Second Semester

GS	302	Modern Labor Problems	(3-0)3
GS	412	Industrial Management	(3-0)3
GS	466	Management Problems	(3-0)3
GS	468	Business Finance	(2-0)2
TE	404	Textile Evaluation	(2-2)3
TE	406	Finishing Technology	(0-4)2
AS	402	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	19 or 20

NOTE: For explanation of the Elective System, see page 65.

Textile Technology

This course of study is designed to equip its students with a well-rounded understanding of the theory and principles relating to the processing of textile materials. At the same time it provides the scientific basis necessary to understand and apply this technological knowledge as well as supplying those subjects from the field of humanities so vital to the development of the adult individual.

The basic purpose of the program is to prepare students to become competent textile technologists for eventual supervisory, administrative, or executive positions within the industry and its allied fields. It is felt that this can best be done by a comprehensive course that covers the basic theory, principles, and applications of the major phases of textile manufacture utilizing all the common fibers, both natural and man-made, and all fabricating processes. Therefore, this course is concerned with a detailed study of such textile topics as fiber sources, availability, properties, characteristics, uses, methods of manufacturing man-made fibers, marketing, grading, sorting, and other preparatory steps. It also deals with the theory of, and its applications to, the fundamental textile operations of fiber processing, yarn manufacture, fabric design, fabric fabrication by means of weaving and knitting, textile finishing, and testing or evaluation.

This program leads to a B.S. degree; hence, such fundamental studies as mathematics, physics, and chemistry are naturally included. However, a maximum amount of time is devoted to the textile and engineering subjects essential to the development of a textile technologist.

The humanities are included to provide a balanced education and to develop the student's ability to express himself clearly as well as to give him an understanding of human behavior.

Any student completing this course should be well qualified to assume ultimately a position of responsibility in any phase of the textile industry, whether it be in processing, technical service, development, or research.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	203	Elementary Organic Chemistry	(3-0)3
EN	205	Mechanism	(3-2)4
MA	205	Calculus and Analytic Geometry	(3-0)3
PH	205	Physics	(3-2)4
TE	201	Fiber Technology	(4-0)3
		Total credit hours	19

*Alternate:

GS	205	Man and His Environment	(3-0)3

Second Semester

*AS	202	Air Science	(2-1)2
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)3
TE	202	Fiber Technology	(3-0)2
TE	204	Yarn Technology	(7-2)5
		Total credit hours	16

*Alternate:

GS	222	Appreciation of Literature	(3-0)3

JUNIOR YEAR

First Semester

EN	311	Heat and Power	(2-2)3
GS	201	Economics	(3-0)3
TE	301	Yarn Technology	(7-6)7
TE	303	Fabric Technology	(3-4)4
AS	301	Air Science, or GS 223, The United States since 1865	3 or 4
		Total credit hours	20 or 21

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
GS	202	Economics	(3-0)3
TE	302	Yarn Technology	(7-6)7
TE	304	Fabric Technology	(3-4)4
AS	302	Air Science, or GS 232, Comparative Literature	3 or 4
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

CH	401	Introduction to Textile Chemistry	(1-3)2
TE	401	Fabric Technology	(5-7)6
TE	403	Textile Evaluation	(2-2)3
TE	405	Textile Technology	(4-2)4
AS	401	Air Science, or GS 301, Economic Development of the United States	3 or 4
		Total credit hours	20 or 21

Second Semester

EN	304	Instrumentation for Textile Processing	(2-2)3
TE	402	Fabric Technology	(5-7)6
TE	404	Textile Evaluation	(2-2)3
TE	406	Finishing Technology	(0-4)2
AS	402	Air Science, or GS 470, Comparative Modern Governments	3 or 4
		Total credit hours	20 or 21

NOTE: For explanation of the Elective System, see page 65.

Subject Descriptions

Subjects are listed alphabetically, regardless of the department involved, under the following headings:

AS	Air Science	LE	Leather
CH	Chemistry	MA	Mathematics
EL	Electronics	PA	Paper
EN	Engineering	PH	Physics
GS	General Studies	PL	Plastics
	TE Textiles		

The number following the letter symbols is composed of three digits. The first digit of the number indicates the college year when the subject is normally presented, e.g.: GS 111 is a freshman-year subject; PA 414 is a senior-year subject. Subjects numbered 500 and above are restricted to graduate students.

Except for basic mathematics, first-semester subjects are designated by odd numbers and second-semester subjects by even numbers. Hyphenated numbers indicate subjects continuing throughout the year. Numbers in parentheses indicate former designations.

Following the names of the individual subjects, the number of lecture-recitation and laboratory hours is indicated within the parentheses and the credit hour is shown outside. In the case of a year course the credit shown is the total for the year.

Examples of the above coding are as follows:

(2-6)4 means 2 hours of lecture-recitation and 6 hours of laboratory for 4 credits; (2-3) (1-6)6 indicates 2 hours of lecture-recitation and 3 hours of laboratory for the first semester followed by 1 hour of lecture-recitation and 6 hours of laboratory the second semester, for a total credit of 6.

The prerequisites for the various subjects are shown in brackets, e.g., [EN 111]. No student can be officially registered in a subject until the indicated prerequisites have been satisfactorily completed.

AIR SCIENCE

AS 101-102 **Air Science I** (2-1)(2-1)4

The history of aviation, principles of flight, and elements of aircraft engines. Global geography and a consideration of international tensions and security structures of various nations of the world. Classes in leadership and drill provide for the development in the student of the qualities of leadership and discipline essential to Air Force officers.

AS 201-202 **Air Science II** (2-1)(2-1)4

Introduction to the elements and potentials of air power. The course considers air power in terms of targets, weapons, aircraft, bases, and operations. Consideration is also given to the USAF Officer Career Program and the moral responsibility of Air Force leaders.

AS 301-302 **Air Science III** (4-1)(4-1)8

Concerns the development of certain specialized intellectual skills in the areas of military law, command and staff, problem solving, communication, and instruction in the Air Force, and certain technical skills in the areas of weather, navigation, and air base functions.

AS 401-402 **Air Science IV** (4-1)(4-1)8

Seminar in principles of personnel management. The framework of international politics, world powers and strategic areas, and the security problem in relation to international power clashes. Principles of warfare and a historical survey of air warfare. Briefing for commissioned service and a leadership laboratory.

CHEMISTRY

CH 101-102 — **General Chemistry** — **(4-2)(4-2)8**

Chemical principles and calculations. Includes the chemistry of both metallic and nonmetallic elements and of their compounds. A brief survey of organic chemistry is included in the second semester.

CH 201-202 — **Organic Chemistry** — **(3-3)(3-3)8**

[CH 102]

The classification, nomenclature, structure, mechanism of reaction, and behavior in bulk of important kinds of organic species. The laboratory work illustrates the experimental techniques which can be used to react, purify, characterize, and identify organic substances.

CH 201M-202M — **Organic Chemistry** — **(3-6)(3-6)10**

[CH 102]

Identical with CH 201-202 except that additional laboratory work in synthetic organic chemistry is given. Required for majors in chemistry.

CH 203 — **Elementary Organic Chemistry** — **(3-0)3**

[CH 102]

This subject enables students not majoring in chemistry to become conversant with the names, structural formulas, properties and uses of some important industrially available organic substances and with the role which organic chemistry plays in industry and engineering.

CH 205 and 206 — **Qualitative Analysis** — **(2-6)4**

[CH 102]

Mass action principles and systematic analysis of inorganic compounds by semi-micro technique. Offered both semesters.

CH 211 and 212 — **Quantitative Analysis** — **(3-6)5**

[CH 102]

The fundamental principles of quantitative analysis. The principles and calculations of gravimetric analysis, including an introduction to mineral separations as well as the analysis of soluble salts; the principles and calculations of volumetric analysis,

including neutralization methods, oxidation-reduction methods, and iodometric methods. Offered both semesters.

CH 290 Introduction to Chemical Engineering (3-3)4
[CH 211]

An introductory study of the principles of material and energy balance, equilibrium, and rate of reaction. Examples are studied in the laboratory. The student is encouraged to develop his initiative and resourcefulness in obtaining experimental data, analyzing results, and communicating his findings by written and oral reports.

CH 302 Introduction to Textile Chemistry (1-3)2
[CH 102]

Lectures for the non-chemist on the various processes preliminary to dyeing. The preliminary treatments given the natural and manufactured fibers are studied as well as the action and properties of the textile chemicals used in these processes.

CH 307 Atomic and Molecular Structure (3-0)3
[CH 102]

Modern concepts of atomic and molecular structures as interpreted through emission, ultraviolet, infrared, and Roman spectra.

CH 311 Textile Quantitative Analysis (2-4)3
[CH 211 or 212]

The examination and evaluation of chemicals utilized in the textile industry. Advanced techniques and instrumental methods are introduced for the analysis of bleaching agents, industrial water, soaps, oils, and synthetic detergents. Group projects and report writing. For students in the Textile Chemistry course.

CH 314 Advanced Quantitative Analysis (2-4)3
[CH 211 or 212]

Advanced principles and techniques of analytical separations with laboratory emphasis on some instrumental methods. The following topics will be considered: fractional precipitation methods, colorimetry, chromatography, compleximetry, potentiometric titrations, polarography, and organic precipitating agents. Group projects and report writing. For students in the Chemistry course.

CH 331-332 Physical Chemistry (3-1½)(3-3)8
[CH 102, MA 206, PH 206]

The formulation and development of the mathematical and mechanical models of theoretical chemistry and their uses in the

solution of the practical problems of chemistry and chemical engineering. Topics included are atomic and molecular structure, states of matter, thermodynamics, thermochemistry solutions, electrochemistry, colloids, chemical equilibrium, kinetics, and photochemistry. CH 331 is for students not majoring in chemistry.

CH 331M **Physical Chemistry** (3-3)4
[CH 102, MA 206, PH 206]

Same as CH 331, but additional laboratory hours are required. Replaces CH 331 for students majoring in Chemistry or Textile Chemistry.

CH 333 **Industrial Stoichiometry** (3-0)3
[CH 211 or 212, PH 205]

A study of some important operations in the chemical industry, e.g., sulfuric acid, and in the pulp and paper industry from the standpoint of the application of reaction rate and mass and energy balance to the prediction of performance, yield, etc. Recirculatory processes are also studied.

CH 334 **General Colloid Chemistry** (3-0)3
[CH 331]

The approach is from the standpoint of the theoretical properties of the colloid system. Interfacial phenomena, particle kinetics, electrical properties, and viscosity characteristics are studied. The preparation of colloid solutions and the character of lyophobic and lyophilic sols, gels and emulsions are developed from the above fundamental properties.

CH 342 **Organic Qualitative Analysis** (1-6)3
[CH 202; CH 205 or 206]

Methods of identification of "unknown" organic substances whose properties have been previously published in the chemical literature.

CH 352 **Chemical Engineering** (3-0)3
[CH 102, CH 331, MA 206, PH 206]

Descriptive and quantitative information on unit conversion, dimensional analysis, materials of construction, flow of fluids, flow of heat, hygrometry, humidification, dehumidification, and drying.

CH 355 **Chemistry and Physics of Fibers** (2-3)3
(CH 252) [CH 202 and 211]

The structure and chemical reactions of linear high polymers of importance in the field of natural and synthetic fibers; the

chemical and physical structure of polymers and fibers; the relation of molecular length, orientation, crystallinity, intermolecular attractions, side chains, and flexibility of polymers to the physical properties of fibers; chemical reactions of polymers and their effects on fibers.

CH 356 **Chemistry of Fiber Purification** **(2-3)3**
(CH 353) [CH 202 and 211]

A study of the impurities present in textile fibers and fabrics and their removal. Both natural and manufactured fibers are taken up. This subject is covered by lecture, laboratory and pilot plant work.

CH 364 **Textile Colloid Chemistry** **(4-0)4**
[CH 331]

Basic principles of surface and colloidal chemistry and their applications in industry. Special emphasis is placed on applications to the textile field: wetting, detergency, and finishing processes, as well as the colloidal behavior of the fibers themselves.

CH 401 **Introduction to Textile Chemistry** **(1-3)2**
[CH 302]

A continuation of CH 302. The application of various classes of dyes to natural and manufactured fibers. Methods of dyeing, fastness properties of different classes of dyes, and the nature and use of dyeing assistants are stressed.

CH 403-404 **Chemistry of High Polymers** **(3-3)(3-3)8**
(CH 375-376) [CH 202]

Definition and classification of high polymers; chemistry of the more important polymers including preparation, physical properties, and chemical properties; mechanism and procedures for polymerization, copolymerization, and condensation; physico-chemical investigations including molecular weight determination and distribution; the structure of high polymers including relationship of structure to properties; inter- and intra-molecular forces; states of aggregation; transition points; elasticity; visco-elastic behavior; cross-linking; plasticization (internal and external); solvent action.

CH 408 and/or 409 **Advanced Studies in Chemistry** **Credits to be arranged**

[Permission of the Chairman of the Chemistry Division and the Instructor]

Advanced work in analytical, organic, inorganic, physical, or textile chemistry. Includes literature survey, laboratory work, and reports.

CH 422 **Chemical Textile Testing** **(2-3)3**
[CH 211 or 212, and 364]

Chemical methods of textile testing. Quantitative as well as qualitative determination of fiber content, finishing agents and dyestuffs. Includes optical methods of analysis and evaluation.

CH 423 **Advanced Organic Chemistry I** **(3-0)3**
[CH 202 and 332]

A discussion of the structure and mechanism of reactions of organic chemical species from the point of view of physical organic chemistry.

CH 424 **Advanced Organic Chemistry II** **(3-0)3**
[CH 423]

The mechanism, limitation, and use of the important reactions of synthetic organic chemistry.

CH 425 **Organic Chemistry of Colored Substances** **(2-0)2**
(CH 354) [CH 201]

The relation between the structure of an organic molecule or ion and its absorption in the ultraviolet or visible spectral region. The synthesis and reactions of selected colored organic substances.

CH 431-432 **Advanced Physical Chemistry** **(3-0)(3-0)6**
[CH 314 and 332]

The principles of thermodynamics, both classical and statistical, and their application to chemical problems. The description of system states and the development of criteria for determining the spontaneity of physical and chemical changes are emphasized. A study of chemical kinetics is also included. The order of reactions, factors that influence rates, and explanations of the rates in terms of hypothetical reaction mechanisms.

CH 441 **Chemical Engineering** **(3-0)3**
[CH 352]

A continuation of CH 352. The unit operations of evaporation, gas absorption, filtration, and washing.

CH 442 **Chemical Engineering Thermodynamics** **(3-0)3**
[CH 332]

A study of the first law of thermodynamics. Heat capacity, perfect gases, phase rule, and generalized pressure, volume, and temperature relations. An introduction to the second law.

CH 443-444 **Advanced Inorganic Chemistry** **(3-0)(3-0)6**
(CH 473-474) [CH 202 and 314]

Advanced chemistry of the common elements and their compounds, including coordination complexes, inorganic stereoisomerism, ion exchange, etc.

CH 446 **Advanced Inorganic Chemistry Laboratory** **(0-3)1**
[CH 202 and 314]

Not offered in 1957-58

Inorganic preparations and advanced techniques.

CH 453 **Theory of Dyeing** **(3-4)4**
[CH 356 and 422]

The mechanism of chemical reactions of the important classes of dyes with natural and synthetic fibers; theory of reactions; mechanisms of chemical additives; physical and chemical variations of fibers; effects of time, temperature, and agitation.

CH 454 **Industrial Dyeing and Printing** **(2-8)4**

The various classes of coal-tar dyes are applied to natural and manufactured fibers. The fastness properties and end use of fibers dyed with different classes of dyes are taken up. Work is also done in color matching, union dyeing, and printing.

CH 461 **Microbiology** **(1-3)2**
[CH 202]

This subject considers the fundamentals of mycological and bacteriological theory briefly but in sufficient detail so that the problem of the microbiological deterioration of textiles, paper, and leather may be discussed. Methods of detecting mildewing, methods of testing textiles for mildew resistance, and bacteriological water analysis are also studied.

CH 464 **Advanced Microbiology** **(1-3)2**
[CH 461]

Work is arranged according to the particular interests of the student and consists of special projects.

CH 481 **Radiochemistry** (1-3)2
[CH 332]

The theory and practice of nuclear chemistry and radiochemistry.

CH 491 **Textile Chemistry Literature Seminar** (2-0)2
[Permission of Instructor]

A study and discussion of current textile chemistry literature, stressing the critical analysis of the subject matter.

CH 501 **Color Measurement for Textile Chemists** (1-3)2
[CH 422 or equivalent]

The operation and use of transmission and reflection colorimeters, spectrophotometers, and recording spectrophotometers. The calculation of results and the use of the instruments in dye application research are also investigated.

CH 503 **Interpretation of Data** (2-0)2

Mathematical methods of analyzing, plotting, and interpreting experimental data. Lectures and exercises.

CH 505 **Physical Chemistry of Dyeing** (2-3)3

A combination of lectures, seminars, and laboratory experiments on the physicochemical principles involved in the application of dyestuffs to textile materials.

CH 507-508 **Chemistry Seminar** (1-0)(1-0)2

CH 512 **The Physical Chemistry of Surface-active Agents** (1-3)2
[CH 364]

A series of lectures and laboratory experiments on the physicochemical principles involved in the use of surface-active agents in textile processing. The surface and bulk properties of the agents are studied and related to the over-all technical properties and uses.

CH 523-524 **Organic Chemistry of Polymeric Species** (3-0)(3-0)6
(CH 451-452) [CH 202, 332, 424]

The classification, mechanism of formation, structure, and properties in bulk of polymeric organic species.

CH 525-526 **Chemistry of the Carbohydrates** (3-0)(3-0)6
[CH 202 and 332]

Starting with the chemistry of the simple sugars, this subject leads to a detailed study of the physical chemistry and the organic chemistry of the important polysaccharides, such as cellulose and starch, and of their industrially important derivatives.

CH 541-542 **Graduate Thesis** **Credits to be arranged**

The graduate thesis is to be an independent investigation of a problem by the student in conference with a faculty advisor and approved by the Department Head. A clear and systematic written presentation of the results is a required part of this subject.

CH 551 or 552 **Textile Testing Problems** (1-3)2
(CH 521 or 522) [CH 422]

Special problems relating to the design and evaluation of improved analytical or testing procedures.

CH 553-554 **Evaluation of Finishing Agents** **Credits to be arranged**
(CH 525 or 526)

A laboratory study designed to teach the use of the various test methods and instruments in evaluating the effect of finishing treatments on the tactile and end-use properties of a fabric.

CH 555-556 **Textile Chemistry Seminar** (2-0)(2-0)4
(CH 531-532)

A series of informal discussions of current problems in research and technology in the textile chemistry field. Special investigations of the literature will be utilized to serve as a source of seminar topics.

CH 559 **Instrumental Methods in Textile Research** (1-2)2
(CH 527)

The use of instruments in textile chemical research. The lectures cover the general principles of instrumentation in the various fields considered. The laboratory exercises invoke the use of specific instruments and are designed to teach the student to make a proper choice of instrumental methods in common textile chemical problems.

ELECTRONICS

EL 201-202 Introductory Circuit Theory (4-0) (4-0) 8
[PH 104 and MA 108; EL 205-206 and 207-208 taken concurrently]

An introduction to the study of the mathematical and physical aspects of electric circuits in which radiation in the form of electromagnetic waves does not play a major role. Resistive circuits, Kirchhoff's laws, Thevenin's theorem, reciprocity of simple circuits, sinusoidal steady-state behavior, vector diagrams, resonance, transients in alternating current circuits, loci of complex functions, polyphase systems, and an introductory discussion of simple nonlinear circuits.

Text: Guillemin, *Introductory Circuit Theory.*

EL 203-204 Elementary Electricity and Magnetism Laboratory (0-3) (0-3) 2
[PH 104; EL 201-202 taken concurrently]

The purpose of this subject is to give the student a working knowledge of the use of common electrical devices and measuring equipment as well as practice in the preparation of circuit drawings, the writing of technical reports, and the analysis of the precision of measurements. Some attention will be given to the practical techniques useful in the construction of electrical equipment and accessories. Among the topics considered in the laboratory are: measurements of resistance, capacitance, inductance and impedance; d.c. and a.c. bridge circuits; magnetic measurements; characteristics of vacuum tubes and other nonlinear devices; elementary vacuum tube circuits; a.c. and d.c. motors, and transformers.

Texts: Stout, *Basic Electrical Measurements;* Dunn and Barker, *Electrical Measurements Manual.*

EL 205-206 Introductory Field Theory (4-0) (4-0) 8
[PH 104 and MA 108; EL 207-208 taken concurrently]

The fundamental laws of electricity and magnetism presented from the point of view of field theory. Free use is made of the calculus. Topics in the first semester include electrostatics, steady currents and their magnetic fields, induced electromotive forces and inductance, elementary alternating current circuits, and time-dependent magnetic fields. In the second semester the following topics are studied: electromagnetic waves in free space, on wires,

and in material bodies; behavior of electrons in metals, thermionic emission, dielectric and magnetic properties of matter, geometrical optics, physical optics, atomic structures, and topics in modern physics.

Text: Frank, *Introduction to Electricity and Optics,* 2nd Edition.

EL 207 — Intermediate Engineering Mathematics — (4-0)4
[MA 108]

A continuation of MA 108. Methods of integration, elementary vector analysis, elements of solid analytic geometry, partial differentiation, multiple integrals, infinite series, and the elements of complex variable theory. Stress is given to the application of the mathematics to problems in applied science and engineering.

Text: Thomas, *Calculus and Analytic Geometry.*

EL 208 — Differential Equations for Engineers — (4-0)4
[EL 207]

A general survey of ordinary differential equations and an introduction to partial differential equations and the Laplace transformation. Numerous applications are made to problems in physics, chemistry and geometry.

Texts: Reddick and Kibbey, *Differential Equations* (3rd Edition) ; Jaeger, *Laplace Transformation;* Peirce, *A Short Table of Integrals.*

EL 301 — Introduction to Physical Electronics — (3-0)(3-0)6
[EL 202 and 208]

The motion of charged particles in electric and magnetic fields, electronic phenomena in metals, statistical electron theory of metals, characteristics of thermionic cathodes, kinetic theory of gases, fundamental processes in gases, electrical discharges in gases, rectifiers and filters, photoelectricity, diodes, gas tubes, photoelectric cells, triodes, and multielectrode tubes.

Texts: Millman and Seely, *Electronics;* Van Name, *Modern Physics.*

EL 303-304 — Electronic Circuits — (3-0)(3-0)6
[EL 202 and 208; EL 301 taken concurrently]

Characteristics of electronic tubes; graphical solutions for circuits containing nonlinear elements; linear equivalent circuits; combinations of resistive, capacitive, and inductive elements; response of basic circuits to simple wave forms; amplifiers; oscillators;

clamping, clipping, and trigger circuits; voltage-regulating circuits; multivibrators; and counting circuits.

Texts: Corcoran and Price, *Electronics;* Martin, *Electronic Circuits.*

EL 305-306 Electronics Laboratory (0-4) (0-4) 4

[EL 202, 204, and 206; EL 303-304 taken concurrently]

The purpose of this subject is to give the student a good working knowledge of a number of electronic circuits and the techniques of measurement for evaluating their performance. A number of these circuits are assembled by the student. Further training is provided in the analysis and reporting of experimental work. Development of the student's initiative, resourcefulness, and independent judgment is encouraged.

Text: Reed, Wagner and Corcoran, *Electrical Communications Experiments.*

EL 307-308 Electromagnetic Devices and Machinery (3-0) (3-0) 6

[EL 202, 206, and 208; EL 311-312 taken concurrently]

Dimensional analysis, free and forced response of dynamic systems, electromechanical analogies; electromagnetic, piezoelectric, magnetostrictive, electrothermal, and electromechanical devices; indicating and recording equipment, electrical computers, and fractional horsepower motors.

EL 310 Electromagnetics (3-0) 3

[EL 202, 206, 208, and 311; EL 312 taken concurrently]

Electricity and magnetism are presented from the field theory point of view. Vector analysis is used throughout and Maxwell's equations are introduced early in the course. The topics covered include the static electric field in polarizable and conducting media, static magnetic fields of steady electric currents and ferromagnetic materials, time-changing electric and magnetic fields, magnetic induction, and boundary value problems associated with static fields.

Text: Kraus, *Electromagnetics.*

EL 311-312 Engineering Mathematics (4-0) (4-0) 8

[EL 208]

Ordinary differential equations, Laplace transformation, numerical methods of solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations, partial

differential equations of mathematical physics, and complex variable theory.

Text: Hildebrand, *Advanced Calculus for Engineers.*

EL 401-402 **Servomechanisms** **(3-0)(3-0)6**
[EL 304 and 312]

A survey of industrial electronic control systems. Among the topics considered are: selsyns, amplidynes, regulators, servomechanisms, magnetic amplifiers, saturable reactors, inverters, high-current rectifiers, and high-voltage machines.

Texts: Brown and Campbell, *Principles of Servomechanisms;* Thaler, *Elements of Servomechanism Theory.*

EL 403-404 **Microwave Electronics** **(3-0)(3-0)6**
[EL 304 and 312]

Practice in the analysis of electronic systems. Beginning with zero frequency circuits, a study is made of the modifications required to give proper behavior as the frequency is increased. Among the topics considered are: radio frequency circuits; television circuits; amplitude, frequency, and pulse modulation; elements of electromagnetic theory, antennas, waveguides, microwave generators and receivers.

Texts: Reich *et al., Microwave Theory and Techniques;* Reintjes and Coate, *Principles of Radar;* Panofsky and Phillips, *Classical Electricity and Magnetism.*

EL 409-410 **Electronic Projects Laboratory** **(0-4)(0-4)4**
[EL 306 and 310]

In this subject the student is given the opportunity to develop, construct, study, modify, and test electronic components and systems. He is expected to carry out his investigations more or less independently. Original investigations are encouraged but not required. The careful preparation of technical reports on the experimental work is emphasized. Where practicable, the student is expected to write his reports using the style of either the *Journal of the Institute of Radio Engineers* or the *Review of Scientific Instruments.*

EL 411-412 **Applied Electronics Laboratory** **(0-4)(0-4)4**
[EL 306 and 310]

The purpose of this subject is to give the student an experimental familiarity with the nature, application, and performance of various electronic devices. Emphasis is given to the preparation of good technical reports.

Text: Terman and Petit, *Electronic Measurements.*

EL 413-414 Thermodynamics and Properties of Materials (3-0)(3-0)6
[EL 301, 310, and 312]

The fundamental concepts of thermodynamics and statistical mechanics with emphasis on applications to the solid state.

EL 415-416 Communications Theory (3-0)(3-0)6
[EL 304]

Theory and applications of thermionic tubes and transistors in amplifiers, oscillators, modulators, and detectors. Principles of television communication.

Texts: Martin, *Electronic Circuits;* Everitt and Anner, *Communication Engineering.*

EL 417-418 Network Analysis (3-0)(3-0)6
[EL 304]

The formulation of general network equations and the development of various equivalent circuits and circuit theorems. The transient behavior of linear networks, characteristics of wave filters, circuits having continuously distributed constants, and other coupling networks.

Text: Van Valkenburg, *Network Analysis.*

EL 419 Basic Principles of Computers (3-0)3
[EL 304 and 306]

Instrumentation principles of analog and digital computers, electromechanical analogies as used for electrical analog computers, basic design of digital computers, and applications of computers to problems in science and engineering.

EL 420 Instrumentation (3-0)3
[EL 304 and 306]

Methods of electrical measurement of physical quantities such as temperature, pressure, velocity, acceleration, radiant energy, ionization, and noise.

EL 501-502 Mathematical Methods for Engineers (3-0)(3-0)6

Elements of function theory, differentiation, integration, space geometry, functions of a complex variable, residues and complex integration, and applications. Algebra of linear equations, vector and tensor analysis, orthonormal functions, integral equations, and variational methods.

Texts: Smith, *Mathematical Methods for Scientists and Engineers;* Page, *Physical Mathematics.*

EL 503-504 **Introduction to Theoretical Physics** **(3-0)(3-0)6**

The student is introduced to the analytical methods of theoretical physics, The major emphasis is placed on prequantum physics. The following topics are covered: the Lagrangian and Hamiltonian formulations of analytical mechanics; special relativity; elasticity and hydronamics, kinetic theory, thermodynamics, and statistical mechanics; electricity and magnetism from the field-variable point of view; Maxwell's equations; and atomic spectra and structure.

EL 505-506 **Microwave Electronics** **(3-0)(3-0)6**
Not offered in 1957-58

Elements of electromagnetic theory, transmission lines, impedance matching, waveguides, antennas, microwave oscillators and amplifiers, klystrons, magnetrons, and travelling wave tubes.

Texts: Reich *et al., Microwave Theory and Techniques;* Reintjes and Coate, *Principles of Radar;* Panofsky and Phillips, *Classical Electricity and Magnetism.*

EL 507-508 **Intermediate Solid State Electronics** **(3-0)(3-0)6**
Not offered in 1957-58

An intensive study of selected topics in solid state electronics.

Texts: Shockley, *Electrons and Holes in Semiconductors;* Slater, *Quantum Theory of Matter;* Peierls, *Quantum Theory of Solids.*

EL 509-510 **Transients in Electromechanical Systems** **(3-0)(3-0)6**
Not offered in 1957-58

Training in the formulation and solution of ordinary and partial differential equations which arise in the treatment of mechanical, acoustical, thermal, and electrical systems. Extensive use is made of modern operational mathematical techniques.

Text: Gardner and Barnes, *Transients in Linear Systems.*

EL 511-512 **Dynamic Control Analysis** **(3-0)(3-0)6**
Not offered in 1957-58

The basic principles of electronic devices used for control and measurement in applied science and engineering.

Text: Truxal, *Automatic Feedback Control System Synthesis.*

EL 513-514 **Electromagnetic Theory** **(3-0)(3-0)6**
Not offered in 1957-58

Maxwell's equations, stress and energy, the electrostatic field, the magnetostatic field, plane waves in isotropic media, cylindrical waves, spherical waves, radiation, and boundary value problems.

Text: Stratton, *Electromagnetic Theory.*

EL 515-516 Elementary Quantum Mechanics (3-0)(3-0)6

Not offered in 1957-58

The postulational formulation of quantum mechanics. The basic theory is developed both in the operator and matrix formulations.

Texts: Schiff, *Quantum Mechanics;* Persico, *Fundamentals of Quantum Mechanics.*

EL 517-518 Solid State and Modern Physics for Engineers (3-0)(3-0)6

Not offered in 1957-58

Elements of electronics, special theory of relativity, atomic structure of matter, quantum mechanics, X rays, molecular structure and molecular spectra, low-temperature phenomena, natural and induced radioactivity, nuclear fission, cosmic rays and mesons, elements of crystal physics, specific heats, alloys of metals, elastic and plastic properties of solids, rupture and fatigue of solids, thermal diffusion, electron theory of metals and alloys, thermal and electrical properties of solids, energy levels in solids, cohesion in solids; magnetic, paramagnetic, and diamagnetic properties of solids; magnetic moments and resonance, transistor physics, semiconductors, and electron diffusion in metals.

Texts: Kittel, *Solid State Physics;* Slater, *Quantum Theory of Matter;* Peierls, *Quantum Theory of Solids.*

EL 519-520 Seminar in Electronics (1-0)(1-0)2

Not offered in 1957-58

Discussion by staff members and students of current journal publications and topics of current interest in electronic science, electronic engineering, and related areas of applied physics.

EL 521-522 Special Problems in Electronics

The purpose of this subject is to give the student an opportunity for individual study, under the direction of a staff member, of topics in or related to electronic engineering.

EL 525-526 Graduate Research

Supervised research on some problem in electronic science, electronic engineering, or in certain areas of applied physics. The results of the research are to be embodied in a thesis acceptable to the departmental committee on graduate study.

ENGINEERING

EN 113 | **Engineering Graphics** | **(0-3)1**

Freehand and instrumental multiview drawing, fundamentals of dimensioning, engineering geometry, isometric sketching, charts and graphs.

EN 114 | **Engineering Graphics** | **(0-3)1**
[EN 113]

Auxiliary views, sectional views, basic descriptive geometry, intersections and developments, fasteners, dimensioning.

EN 201 | **Machine Drawing** | **(0-3)1**
[EN 114]

Several short problems involving centers of gravity, cam layouts, counterweights, welding, limit dimensioning, and graphical calculus.

EN 203 or 204 | **Mechanism** | **(3-0)3**

The basic principles of kinematics, in which the wide variety of process machinery available furnishes many specific examples. Frequent use of these mechanisms is made in the development of the subject. Some of the important topics covered are the following: rolling cylinders and cones, gearing, gear train design, epicyclic gear trains, flexible connectors including stepped pulley and cone design, cam design, linkages, and miscellaneous mechanisms.

EN 205 | **Mechanism** | **(3-2)4**

Similar to EN 203, except that laboratory time has been provided to allow study of textile mechanisms.

EN 207 | **Machine Drawing** | **(0-6)2**
[EN 114]

Short problems involving centers of gravity, cam layouts, counterweights, piping diagrams, welding, assembly drawings, limit dimensioning and tolerances, and graphical calculus.

EN 211 or 212 | **Machine Tool Laboratory** | **(1-2)1**
(EN 122)

The objective of this subject is to give the student an insight into the processing of metals through lectures and practical labora-

tory applications covering the basic machine tools such as the lathe, shaper, drill-press, and milling machine, and also the uses of measuring instruments, threads, and gears. Lectures and demonstrations cover topics such as pattern work, foundry practice, die-casting, welding, and forging.

EN 222 or 223 — Applied Mechanics I — (3-0)3
[MA 108, PH 103]

The fundamentals of statics and kinetics, including such topics as force systems, laws of equilibrium, centers of gravity, moments of inertia, and analysis of stresses in framed structures.

EN 232 — Engineering Materials — (3-0)3
[PH 205]

The manufacture, properties, and uses of important ferrous and nonferrous metals; hot and cold processing, alloying, heat treatment; also the properties and use of nonmetallic engineering materials such as timber, cement, concrete, rubber, plastic, and mechanical fabrics.

EN 234 — Plastics Mold Design and Construction — (1-2)1
[EN 211 or 212]

The purpose of this course is to acquaint plastics engineering students with the basic principles of mold design and construction in addition to machining and finishing operations of plastics. Sufficient laboratory time is provided to allow for the design and construction of simple molds.

EN 301 — Applied Mechanics II — (3-0)3
[EN 222, MA 206]

Momentum, energy, work and power, the dynamics of the translation and rotation of rigid bodies, and free and forced vibrations.

EN 302 — Applied Mechanics III — (3-0)3
[EN 301, MA 206]

Continuous beams, compound beams and columns, eccentric loading, combined stresses, reversals of stress, impact stresses, vibrations, and stress analysis by strain gage methods.

EN 303 — Electrical Circuits — (3-2)3
[MA 206, PH 205]

Ohm's law and Kirchhoff's laws, direct current networks, Thevenin's theorem, impedance, representation of alternating

quantities by vectors, sinusoidal steady-state properties, power, series and parallel resonance, polyphase systems, network theorems for steady-state alternating current circuits, coupling networks, transients in simple circuits, Fourier series.

EN 304 Instrumentation for Textile Processing (2-2)3
[PH 104 and 205]

A study of indicating and recording instruments used to measure such common textile process variables as pressure, temperature, humidity, liquid level, fluid flow, etc. An introduction also to electronic circuitry as it relates to textile processing instrumentation controls.

EN 305 Thermodynamics (3-0)3
[MA 205]

The thermodynamic system; the first law of thermodynamics; internal energy; ideal gases; flow of fluids; the second law of thermodynamics; reversibility; entropy and availability; the temperature scale; properties of liquids, gases, vapors, and mixtures; thermodynamic processes.

EN 307 Surveying and Structures (3-3)4
[EN 222]

The fundamental principles of plane surveying, topographic surveying and mapping, principles of structural engineering, algebraic and graphical analysis of forces, calculation of allowable floor loads, stresses in beam and allowable loads on columns.

EN 308 Structures (3-0)3
[EN 307]

Rigid frames analysis, wind stresses, stresses in riveted trusses, reinforced concrete structures, footings, foundations.

EN 309 Machine Tool Fundamentals (2-2)3
[EN 211 or 212]

Basic mechanics of metal cutting. The effects of heat, rake, clearance, lubricants, and coolants on the cutting process. Application of principles to special problems in turning, milling, drilling, grinding, and polishing. Survey of current technical literature and special topic assignments.

EN 311 Heat and Power (2-2)3
[PH 205]

Similar to EN 403 but briefer and designed for those not majoring in engineering.

EN 313 or 314 **Advanced Mechanism** **(2-2)3**
[EN 203]

The graphical and mathematical analyses of advanced mechanisms found in various machines. The forces in, and velocities of, the various members of the mechanism are determined from actual data taken from the machines by the student. The subject is terminated with a problem in the design of a mechanism.

EN 316 **Heat Engineering** **(3-2)4**
(EN 403) [EN 203 and 305]

Applications of the basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A treatment of steam-generating units, turbines, and pumps.

EN 325 or 326 **Applied Mechanics** **(3-0)3**
[MA 108, PH 103]

The fundamentals of statics, including such topics as force systems, laws of equilibrium, friction, centers of gravity, moments of inertia, and an introduction to dynamics.

EN 328 **Strength of Materials** **(3-0)3**
[EN 325]

Principles of the strength of materials with special emphasis on their applications to plastics. Includes such topics as bending and shearing stresses, torsion, compound beams and columns, reversals of stress, impact, vibrations, stress analysis by strain gage methods, concepts of creep and relaxation.

EN 331 or 332 **Strength of Materials** **(3-0)3**
(EN 327) [EN 325]

This subject covers such topics as stress fundamentals, strain bending moment and deflection, beam design, torsion, columns, combined stresses, reversals of stress, and impact.

EN 342 **Principles of Electrical Engineering** **(3-2)4**
[PH 321]

The greater part of the subject is devoted to direct-current generators and motors with a study of their construction and characteristics. Three-phase circuits and alternators are also considered. The accompanying laboratory work illustrates the various methods of measuring polyphase power and of determining the characteristics of direct-current generators and motors.

EN 344 **Electrical Machinery** **(3-2)4**
[PH 321]

A condensation of EN 342 and EN 401.

EN 351 or 352 **Statistical Methods** **(3-0)3**
[MA 108]

The fundamental statistical measures and methods required for the analysis of experimental data; also the practical applications of statistical analysis to quality control and to the planning of industrial experiments.

EN 401 **Principles of Electrical Engineering** **(3-2)4**
[EN 342 or PH 322]

Alternator regulation, parallel operation, single-phase and three-phase transformers, induction motors and their applications to the textile industry, starting devices for motors, synchronous motors, and correction of power factor.

EN 402 **Electrical Control Systems** **(3-2)4**
[EN 401]
Not offered in 1957-58

The operation of simple servomechanisms, potentiometers, synchros and related error detectors, double-speed synchronizing networks, demodulators and modulators, electronic amplifiers, servomotors, magnetic and rotating amplifiers, design of servomechanisms, tests of servomechanisms.

EN 403 **Principles of Heat Engineering** **(3-2)4**
[EN 203, MA 205, PH 104]

The basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A brief treatment of steam engines, turbines and pumps. Special consideration is given to the use of steam in manufacturing processes.

EN 404 **Heat Transfer** **(2-0)2**
[MA 205, PH 104]
Not offered in 1957-58

Conduction, convection, and radiation. Steady and unsteady state of conduction. Heat transfer in tubes and from plane surfaces. Heat exchangers, fin tube radiators, emissivity, and absorptivity.

EN 405 **Electronic Controls and Power Circuits** (3-2)4
[PH 205]

Power requirements in single-phase and three-phase power circuits; operating characteristics of various types of direct-current and alternating-current motors and their manual and automatic controls; industrial electronics including photoelectric relays, time delay relays, motor control, and side register control as applied in the plastics industry.

EN 406 **Fluid Mechanics** (3-2)4
[MA 205, PH 205]

Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs; orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids; Mach's number; dynamical similitude and Pi theorem.

EN 407 or 408 **Fluid Mechanics** (3-0)3
(EN 507 or 508) [MA 205, PH 205]

Similiar to EN 406 but without laboratory work.

EN 411 or 412 **Advanced Heat Engineering** (3-2)4
[EN 316]

Elements of the design of power plants and heating systems, internal combustion engines, and related subjects.

EN 420 **Industrial Instrumentation** (2-3)3
[PH 205]

Similar to EN 422 with the addition of three hours of laboratory per week.

EN 422 **Industrial Instrumentation** (2-0)2
[PH 205]

Modern methods of measurement and control of the more common process variables such as temperature, pressure, liquid level, and fluid flow; response characteristics of mechanical, electric and electronic instruments; modes of control; associated mechanical and electrical mechanisms; characteristics of final control elements; closed-loop control systems; process characteristics and their effects upon the selection of the correct mode of control.

EN 427-428 **Machine Design** (2-3)(2-3)6

[EN 302]

Not offered in 1957-58

The design of machine elements, such as fasteners, shafts, frames, bearings, gears, clutches, springs, keys and drives. Data for most of the problems are taken from actual machines in the various laboratories.

EN 430 **Engineering Design of Textile Structures** (3-0)3

Not offered in 1957-58

This subject correlates engineering properties of textile materials, engineering principles, and textile processing in the design of textile structure with desired properties. The geometry of yarns and fabrics; design of textile structures for certain functional uses; prediction of dimensional changes which occur during use; stresses, strains, and energy changes which the end use imposes; analyses of load-elongation diagrams of textile structural material.

EN 431 or 432 **Advanced Physical Textile Testing** (2-3)3

Compression testing, engineering properties of fibers and yarns, stress-strain-time phenomena of viscoelastic materials, theory and operation of strain gage testing machines, methods of measurement of yarn evenness, thermal transmission, flexibility of fabrics, fabric friction, bursting stress, and crimp. Use of the microscope in determination of wool quality, filament area and number. Statistical analysis of data.

EN 433 **Manufacturing Tools and Methods** (3-0)3

Not offered in 1957-58

Designed to familiarize students with manufacturing methods and machines in general industrial work. Plant layout and planning; machine tool performance; power transmission and control; product evaluation and quality control.

EN 502 **Statistical Quality Control** (3-0)3

[EN 351 or 352]

A study of the various types of control charts for maintaining quality of manufactured products and of the several types of sampling plans for the reduced inspection of manufactured products and of raw materials. Applications of the foregoing statistical techniques to industry in general are discussed, with special emphasis on their application to the textile and other industries.

EN 503 or 504 **Air Conditioning** **(2-2)2**
[PH 205]

The fundamental principles of heating, ventilating, and refrigeration. The laboratory consists of design problems in the air conditioning of industrial buildings.

EN 505 or 506 **Methods of Experimental Stress Analysis** **(3-1)3**
[EN 302, MA 205, PH 205]

An introduction to some of the experimental techniques used in stress analysis. Photoelasticity, electrical strain gages, brittle coating, and mechanical gages are considered in relation to the analysis of both static and dynamic stresses. Special attention is given to the application of these techniques in the study of textile structures and machinery.

EN 509 or 510 **Advanced Statistical Methods** **(3-0)3**
[EN 351 or 352]

A continuation of EN 351 or 352 with particular study of the more advanced statistical techniques as applied to the design of industrial experiments and to the analysis and interpretation of the resulting data.

EN 511-512 **Graduate Thesis** **Credits to be arranged**

Each graduate student in Textile Engineering is required to submit a thesis which shows ability and originality in the solution of a research project.

EN 513-514 **Graduate Seminar** **(1-0)(1-0)2**

Required of all graduate students in Textile Engineering.

GENERAL STUDIES

GS 101-102 World Economic Geography (2-0)(2-0)4

Through a study of this subject the student gains an appreciation of the economic status of the different geographic areas of the world. The effect of climate, the geographic structure, and the distribution of important raw materials upon the activities of the people inhabiting those areas and on the types of industry which support the economic life of the various regions.

GS 111 English Composition and Reading (3-0)3

Training in the basic principles of correct and clear expression. Concentration on paragraph construction and development leading to effective expository writing. Analysis and discussion of the composition and content of collateral reading. Regularly assigned written exercises and individual conferences.

GS 112 English Composition and Reading (3-0)3

Training in the composition of extended written exercises. Introduction to the elementary research techniques of outlining, note taking, footnoting, compiling bibliographies, and more intensive use of the library. Critical analysis and discussion of collateral reading in the sciences and humanities. Regular individual conferences.

GS 122 Perspective Drawing (1-1)1

A mechanical method of representing objects of three dimensions, showing correct proportions as they appear to the eye.

GS 132 Freehand Drawing (0-3)1

Freehand drawing of objects of different textures. Visual training and graphic expression to build a drawing vocabulary which will aid in advanced drawing subjects.

GS 201-202 Economics (3-0)(3-0)6

The principles and practices of economics and a brief study of economic history.

GS 205 or 206 Man and His Environment (3-0)3

The biological aspects of fundamental problems of heredity and environment which confront man in his economic, social, and cultural life. Emphasis is given particularly to the fields of ecology, genetics and eugenics, evolution, and anthropology.

GS 209 or 210 **Speech** **(2-0)2**
[GS 112]

The aim of this subject is to achieve effective delivery of various types of speech. All kinds of delivery are studied and analyzed.

GS 211 or 212 **Business English** **(2-0)2**
[GS 112]

Analysis and practice in letter writing and a study of the basic forms of technical exposition, forming a background for report writing in advanced courses and in industrial activity.

GS 213 **Communication of Ideas** **(3-0)3**

Study and interpretation of assigned readings in the several forms of nontechnical writing, such as the novel, short story, drama, essay, and poetry, with the purpose of familiarizing the student with the methods by which thought is communicated. Skill in presenting ideas is developed through written assignments, including essays or reports of an analytical or critical nature, through oral expression by panels and committees, and through individual oral presentation of assigned subjects.

GS 214 **Technical and Scientific Writing** **(3-0)3**

Thorough grounding in the special demands of technical and scientific exposition, including reports, technical and business correspondence, and research papers, supplemented by readings in technical and scientific fields. Practice in oral communication in connection with the presentation of abstracts, summaries, and reports based on readings and on problems coordinated with the written requirements of other departments.

GS 222 **Appreciation of Literature** **(3-0)3**
[GS 112]

The principles of literary appreciation and criticism. An analysis of prose and poetical selections, with directed investigation of the various literary appeals—the intellectual, the sensory, the emotional, the aesthetic, the imaginative, and the philosophical.

GS 223 or 224 **The United States since 1865** **(3-0)3**

A survey of the advancement of the American people from the Reconstruction Era through World War II.

GS 226 **World History since 1900** **(3-0)3**

Particular attention is paid to the years 1919-1939 and such topics as the rise of new states; the origin and development of new concepts of nationalism, racism, and other phenomena; the align-

ment of world powers for World War II; and the role of the United States in mid-twentieth-century reconstruction.

GS 232 Comparative Literature (3-0)3

A consideration of at least six classics of western civilization as keys to the development of literary types. An attempt to deduce standards of critical judgment. Class discussions and critical papers.

GS 261-262 Technical German (3-0)(3-0)6

The basic elements of German, leading to the development of reading ability in scientific German.

GS 301 Economic Development of the United States (3-0)3

A brief review of the background of the present economic system and an intensive study of the influence of science and technology upon our economic development. The central theme is the dominant role of the science and technology of our time in present-day American life.

GS 302 Modern Labor Problems (3-0)3

A study of the backgrounds of present-day labor organizations and modern labor law with particular emphasis upon current labor problems in the United States. The major objective of the semester is to familiarize upper-class students with the procedures and techniques of collective bargaining with special attention to the formulation and administration of various types of labor contracts.

GS 303 Psychology (3-0)3

The place of psychology in the life of the individual and society. Physiological bases of behavior and experience, attention, perception, memory, thinking, emotions, intelligence, and personality in terms of the whole person in his social setting.

GS 311 Economic Statistics (3-0)3

Basic concepts of the statistical method with special emphasis on those approaches of most interest to the student of management. Topics covered include measures of central tendency, graphic methods, dispersion, skewness, sampling, normal curve, index numbers, correlation, time series, secular trend, seasonal variation, business cycle, and statistical forecasting.

GS 313 Money and Banking (3-0)3

Monetary and banking systems, particularly those in the United States. Monetary theory and standards, the Federal Reserve, individual bank management, fiscal and credit policies.

GS 314 **Philosophy of Science** **(3-0)3**

This subject analyzes the methods and techniques of inductive and deductive science. Elementary logic is studied and applied to the necessary structure of scientific systems. The great concepts and generalizations which have marked the history of science are reviewed and analyzed, as well as the interrelation of science and general philosophy.

GS 321-322 **Marketing Principles and Problems** **(3-0)(3-0)6**

GS 321 can be taken independently for credit.

GS 321—A study of the problem of marketing especially from the point of view of the formulation of business policy. Topics considered include merchandising, product policy, retailing, wholesaling, marketing problems of manufacturers, and channels of distribution for both consumer and industrial goods.

GS 322—Among the topics considered are product identification and branding, promotional policies, price determination, price policies, price legislation, and marketing and the government.

GS 341 **Accounting - I** **(3-0)3**

The economic significance of accounting, the underlying accounting theories, and the organization and use of modern accounting records. The preparation and interpretation of reports and statements of financial position. The balance sheet, profit and loss statement, theory of debits and credits as applied to journalizing, and the usage of the various ledgers. Cost accounting methods and systems as applied to industry.

GS 342 **Accounting - II** **(3-0)3**

A continuation of GS 341 with emphasis on partnership and corporate records. Payroll and tax accounting; installment and branch accounting techniques. The peculiar aspects of manufacturing accounting are covered in detail, with the application of cost principles to this area.

GS 351 **Elements of Marketing** **(2-0)2**

A survey of marketing principles. The topics covered correspond to those offered in GS 321-322. Readings in current journals, books, and magazines are required as a supplement to the textbook.

GS 361-362 **Advanced Technical German** **(3-0)(3-0)6**
[GS 262 or equivalent]

GS 361 may be taken without continuing GS 362.

This subject is designed to expand the student's elementary understanding of the language, increase vocabulary, and develop

reading aptitudes in special fields of interest selected by the student.

GS 401 or 402 Industrial Relations Seminar (2-0)2
[Permission of Instructor]

This subject gives a small, selected group opportunities to meet with the instructor and occasional visitors in discussion of current problems in industrial relations. Case material and hypothetical problems in modern labor management provide the basis for group study.

GS 412 Industrial Management: Principles and Problems (3-0)3

Backgrounds of modern industry, organization of the industrial enterprise, the operation of modern industry, and coordination of the productive processes. Among the topics covered are risks, forecasting, financing, product development, plant layout, production controls, personnel management, time and motion studies, job evaluation, and wage and salary administration. The text material is supplemented with current readings and case material.

GS 442 Foreign Trade (3-0)3
Not offered in 1957-58

The growth and development of foreign trade, theory of international trade, international commercial policies, foreign trade services, export management, importing and international finance.

Offered in alternate years.

GS 443 Advertising Principles and Problems (3-0)3

A study of the basic principles of advertising and their application to the solution of practical problems encountered by business managers. Functions of advertising; relationship between marketing methods and use of advertising; determining basic promotional strategy; use of consumer advertising to create demand for a type of product or an individual brand; use of contests, premiums, and other strong stimuli to create quick buying action; role of dealer promotion in selling strategy; timing of selling efforts; selection of media; determining the advertising appropriation; and advertising research.

GS 444 Sales Management (3-0)3

Planning the product, including product development, testing, branding, packaging, labeling, warranties, and service; sales organization; sales programs and campaigns; management of the sales

force, including selection, training, compensation, supervision; and control of sales operations.

Offered in alternate years.

GS 461 — Personnel Management — (3-0)3

A comprehensive study of modern labor management techniques in the recruiting, selection, training, and placement of members of the work force. Personnel administration agencies and procedures, with special attention to such matters as employee health and safety, welfare and recreation programs, wage and salary administration, training and education, and management relations with labor organizations.

GS 463 — Business Law — (3-0)3

The basic principles of commercial law including contracts, agency, sales, partnerships, corporation, negotiable instruments, bailments and carriers, insurance, personal property, real property, suretyship and guarantee, and bankruptcy.

GS 465 or 466 — Management Problems — (3-0)3
[Permission of Instructor]

Research for graduate students and selected seniors. Working under the guidance of the instructor, a student investigates an approved topic in the fields of finance, production, or distribution. The findings of the student are presented in formal thesis form. These theses are then placed in the department library for permanent record.

GS 468 — Business Finance — (2-0)2

The organization and financing of private enterprise, partnership, trust, and corporate types of business establishments. The stock and bond markets. Emphasis is placed on the study of the corporation in formation, operation, dissolution, and reorganization.

GS 469 or 470 — Comparative Modern Governments — (3-0)3

A study of twentieth-century political thought and the structure and functions of government agencies in democratic and totalitarian political systems. Emphasis is given to new concepts of government authority and responsibility and to changing patterns of international relations.

GS 471 or 472 — American Foreign Policy, 1774 to the Present — (3-0)3

A study of the development of U. S. foreign policy from the beginnings of the Republic to our present position in world affairs. Particular attention is given to the influences of two world wars and their aftermaths upon American participation in global politics.

GS 473 — Modern Drama — (3-0)3

A survey of major forces in the theater from the time of Ibsen to the present. Selected representative plays of American and European dramatists are read and discussed.

GS 475 — The Modern American Novel — (3-0)3

A consideration of outstanding American novelists from 1920 to the present. Selected works of Faulkner, Fitzgerald, Hemingway, Wolfe, and others are read. Discussion of novels of war, satire, social protest, and "hard-boiled" realism.

GS 478 — Literature of the Bible — (3-0)3

An analytical study of the unfolding drama of the greatest piece of literature that has ever been written. Several books of both the Old Testament and the New Testament are reviewed as literary documents, paying special attention to the authorship and the historical significance of each.

LEATHER

LE 202 — **Applied Leather Analysis** — (1-4)2
[CH 101-102]

A subject designed to acquaint the student with the accepted methods of analysis of the American Leather Chemists Association and other supplementary procedures.

LE 301-302 — **Leather Technology** — (3-6)(3-6)10

Introduction to the technology of leather manufacture. The first semester is devoted to examining government regulations in imported hides and skins, studying the purchasing of hides and skins, and classifying various hide damages. This is followed by work on the handling of raw stock at the tannery, unhairing, bating, and hide classification. The second semester is concerned primarily with the study of vegetable tanning, chrome tanning, and various other types of tanning. In the work throughout the year the material covered in lectures is supplemented by laboratory studies on a small scale.

LE 303 — **Leather Histology** — (2-4)4
[CH 201-202]

A study of the structures of animal skin and of the changes which they undergo in the leather-making process. Because the basically extracellular nature of skin demands it, considerable time is devoted to the nature and function of the fundamental protein constituents.

LE 304 — **Advanced Leather Histology** — (2-4)4
[LE 303]

A study of the fibers of leather in their relationship primarily to the mechanisms of tanning and secondarily to pathological situations and to the physical characteristics of leather.

LE 401-402 — **Leather Technology** — (3-6)(3-6)10
[LE 302]

A continuation of the study into the technology of leather manufacture covering the various currying treatments applied to rough leather, such as fatliquoring, stuffing, dyeing and the various mechanical operations of setting, stretching, etc. It is intended to show how widely the physical properties of leather may be varied and controlled by the proper application and selection of these numerous operations and treatments.

LE 404 **Properties of Leather** **(2-3)3**
[EN 351 and LE 401]

A practical and theoretical study of the characteristics of leather in relation to the end use. Studies are made on measuring and classifying the effect of changes in manufacturing procedure, both chemical and physical. Leather, because it is a natural product, varies considerably within the same hide. Thus, the nature of this variation is very important and the study of any changes affecting it is, in turn, important.

LE 405 **Leather Seminar** **(1-0)1**

A seminar on recent advances in leather research. Written and oral reports are required, and time is devoted to techniques of proper presentation of these reports.

LE 406 **Leather Seminar** **(1-0)1**

A continuation of LE 405.

LE 411-412 **Leather Problems** **(1-6)(1-6)6**
[LE 302]

This subject is designed primarily to enable the student to put into practical application the various scientific principles of physics, chemistry, mathematics, economics, etc. on problems of an industrial nature. This may encompass anything from the design and layout of any of a number of special leather plants to the suggested solution of practical problems which arise in the operation of a modern leather business.

MATHEMATICS

MA A **Plane Trigonometry and Logarithms** **(2-0)0**

Offered only in 1957-58

Angles and trigonometric functions, the logarithm concept, computing with logarithms, solutions of right and oblique triangles with applications, transformations of the functions, graphs and the periodic nature of trigonometric functions, and trigonometric equations.

MA 107 **Introduction to Mathematical Analysis** **(4-0)4**

This subject is intended to provide a firm foundation for the student's subsequent studies in the nature and the use of mathematical functions. Topics considered include functions and graphs, logarithmic and exponential functions, the differentiation and integration of simple functions together with applications involving related rates, differentials, maxima and minima, areas, volumes, lengths of curves, pressure, and work.

MA 108 **Calculus and Analytic Geometry** **(5-0)5**

[MA 107]

The conic sections; equations of motion; Mean Value Theorem; the differentiation and integration of trigonometric, inverse trigonometric, logarithmic, and exponential functions; centroid and center of mass; the theorems of Pappus; moment of inertia; polar coordinates; determinants; synthetic division; properties of roots of higher-degree functions; the translation and rotation of curves; hyperbolic and inverse hyperbolic functions; and further applications to chemistry and physics.

MA 205 **Calculus and Analytic Geometry** **(3-0)3**

[MA 108]

Integration by parts, integration by partial fractions, other integral forms, parametric equations, differentiation of vectors, tangential and normal vectors, elementary vector analysis, solid analytic geometry, partial differentiation, multiple integrals, infinite series, and complex functions.

MA 206 **Differential Equations** **(3-0)3**
[MA 205]

The solution of ordinary differential equations and of partial differential equations of the first order and first degree and of forms in certain other orders and other degrees that lend themselves readily to solution. Practical applications to chemistry and engineering.

MA 301-302 **Advanced Calculus** **(3-0)(3-0)6**
[MA 206]

A further study of differential equations. The Laplace transformation, numerical methods for solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations arising in mathematical physics, and problems suitable for the use of a complex variable. Extensive applications.

MA 306 **Theory of Equations** **(3-0)3**
[MA 108]

Mathematical induction, complex numbers, integral and rational roots, solution by radicals, impossibility of certain geometrical constructions, number of real roots, isolation of a root, determinants, and approximate methods of solution.

MA 403-404 **Mathematical Techniques in the Physical Sciences** **(3-0)(3-0)6**
[MA 302]
Not offered in 1957-58

A subject designed to provide a knowledge of the more important mathematical functions and their properties and to develop facility in applying mathematical methods and techniques to problems in theoretical and applied physical science.

MA 406 **Mathematical Statistics** **(3-0)3**
[EN 351, MA 205]
Not offered in 1957-58

Measurements of dispersion, theoretical frequency distributions, tests of goodness of fit and independence, partial and multiple correlations; permutations, combinations, and probability; game theory.

MA 511 **Functions of a Complex Variable** **(3-0)3**
Not offered in 1957-58

MA 512 **Fourier Series and Boundary Values** **(3-0)3**
Not offered in 1957-58

MA 513 **Tensors and Matrices** (3-0)3

Not offered in 1957-58

MA 514 **Operational Mathematics** (3-0)3

Not offered in 1957-58

MA 515 **Mathematics of Engineering Systems** (3-0)3

Not offered in 1957-58

The solution of linear differential equations by classical methods and by modern methods, and the solution of nonlinear differential equations by various methods.

MA 591 or 592 **Graduate Thesis** **Credits to be arranged**

The graduate thesis covers an independent investigation undertaken by the student of a problem which is of interest to a member of the faculty and has the prior approval of the Department Head. The thesis must show ability and originality and must be a clear and systematic written presentation of the results.

PAPER

PA 301 | **Pulp Technology** | **(3-0)3**
[CH 211]

Lectures and problems concerning the technology of pulp manufacture by the ground-wood, sulfite, alkaline and semi-chemical processes. Bleaching methods are studied.

PA 302 | **Paper Technology** | **(3-0)3**
[CH 211]

Lectures and problems concerning the technology of paper manufacture. Material covered includes stock preparation, filling and loading, sizing, coloring, special additives, paper machine operation, and finishing.

PA 303 | **Pulp Laboratory** | **(2-6)4**
[CH 211]

This as well as subsequent laboratory work is designed with a research-type approach to develop the student's ability to plan and analyze the experimental work and to reach logical conclusions from the results. Studies are made of the principle wood, rag and wastepaper pulps. The work includes wood and pulp microscopy, bleaching, and evaluations of pulps for their papermaking value by physical and chemical testing methods. Detailed written and oral reports are required.

PA 304 | **Paper Laboratory** | **(2-6)4**
[CH 211]

Studies of the fundamental processing techniques used in paper manufacture. The work includes investigations of stock preparation, filling and loading, coloring, use of additives, and sheet formation. Detailed written and oral reports are required.

PA 401-402 | **Practice Work in Industry** | **(1-8)(1-8)8**
[PA 302 and 304, or equivalent]

In order to give the student as thorough a knowledge of industrial problems and practices as possible, it is planned, in cooperation with several mills and converting plants, to set up practice stations. The student will spend one full day each week at one of these stations working on technical problems of interest to the mill management, but under the supervision of a member of the Institute staff. May be taken either or both semesters.

PA 403 **Converting Technology** **(3-0)3**

[PA 302 and 304]

Lectures and problems concerning the technology of paper and paperboard conversion by mechanical, coating, impregnating, laminating and printing processes.

PA 405 **Converting Laboratory** **(2-6)4**

[PA 403, usually taken concurrently]

Study of and practice in the use of the common techniques employed in the paper and paperboard industry. Emphasis is given to the colloidal and rheological properties of materials used. Detailed written and oral reports are required.

PA 408 or 409 **Mill Inspections** **(1-4)2**

Mill visits involving the observation of operations in various types of pulp, paper, paperboard, and converting mills. A formal, detailed written report of the observations made on each visit is required.

PA 413 or 414 **Paper Problems** **(2-6)4**

The senior is given an opportunity to work on a problem connected with some phase of the pulp, paperboard, or converting industry. Original application of accumulated knowledge of chemical and engineering principles is expected. Problems are selected by the student in collaboration with the staff and an advisory committee from the industry. One detailed formal report is required.

PA 501-502 **Graduate Thesis** **(1-9)(1-9)8**

Every graduate student is required to prove his ability to carry on independent research by presenting a thesis on an approved subject.

PA 503-504 **Plant Design** **(4-0)(4-0)8**

[CH 333, CH 442, PA 302]

Design of a paper, boardmaking, or converting process and plant. Included are the material and labor requirements, equipment selection (or design where commercial equipment is not available), the plant layout, and complete economic analysis. One detailed, formal written report including blueprints of equipment and plant layout is required. Principal reference texts: Vilbrandt, *Chemical Engineering Plant Design;* Tyler, *Chemical Engineering Economics.*

PA 505-506 Advanced Papermaking and Paper Converting (2-6)(2-6)8

Nonfibrous raw materials used in the specialty papermaking and paper-converting fields with emphasis on recent developments and new uses. These materials are studied with regard to their chemical and physical properties, the technology of application, and processed sheet properties.

PA 507-508 Graduate Seminar (1-0)(1-0)0

Every graduate student is required to attend a weekly seminar with the staff. Student thesis progress, articles in recent literature, and unpublished recent developments in the field are discussed.

PHYSICS

PH 103 | **Physics** | **(4-1)3**

[MA 107 taken concurrently]

The principles of mechanics, including composition and resolution of vectors, statics, moments, rectilinear motion, Newton's second law, motion of a projectile, work and energy, impulse and momentum, circular motion, rotational kinematics and dynamics, elasticity, harmonic motion, hydrostatics, hydrodynamics, and viscosity.

PH 104 | **Physics** | **(4-1)4**

[MA 108 taken concurrently, PH 103]

Heat, sound, and the basic principles of electricity and magnetism, including the following topics: thermometry, quantity of heat, change of state, heat transfer, thermal properties of matter, the first and second laws of thermodynamics, wave motion, vibrating systems, acoustical phenomena, Coulomb's law, potential, d.c. circuits, the magnetic field, galvanometers, ammeters, voltmeters, wattmeters, the d.c. motor, magnetic field of a current and of a moving charge, induced electromotive force, capacitance and inductance, and magnetic properties of matter.

PH 205 | **Physics** | **(3-2)4**

[MA 205 taken concurrently, PH 104]

Electricity and optics, including the following: transients in circuits containing inductance, capacitance, and resistance; thermoelectricity; ferromagnetism and ferroelectricity; alternating currents; electromagnetic waves; electronic phenomena; the nature and propagation of light; reflection and refraction at a single surface; lenses and lens aberrations; optical instruments; illumination; color; chromaticity diagrams; interference and diffraction; resolution; polarized light; and properties of crystals.

PH 206 | **Physics** | **(3-2)3**

[PH 205]

Modern physics, including the atomic nature of matter and electricity, variation of mass with velocity, isotopes, the nature of radiant energy, black bodies and the origin of the quantum theory, photoelectricity, spectra, Bohr's theory of the atom, X-ray spectra, waves associated with material particles, the spinning electron, Pauli's principle, magnetic moment of an atom, the periodic sys-

tem and quantum numbers, molecular structure, radioactivity, elementary particles, scattering and absorption of particles and photons, transmutation, fission, reactors, fusion, cosmic rays, mesons, hyperons, and relativity.

PH 211 **Intermediate Mechanics** **(3-0)3**
[MA 206 taken concurrently, PH 104]

Reference frames, polar notation, products of vectors, forces, couples and moments, shearing and bending, motion of a particle and of a rigid body, particle dynamics, rigid-body dynamics, gyroscopic phenomena, d'Alembert's principle, work and kinetic energy, potential energy and virtual work, mechanical vibrations in one dimension, critical damping, motion in a conservative force field, potential, deformable bodies in equilibrium, mechanics of an ideal fluid, Euler's equations, wave motions, and kinetic-molecular theory.

PH 222 **Intermediate Heat and Thermodynamics** **(3-0)3**
[MA 205 taken concurrently, PH 104]

Thermodynamic systems, the first law of thermodynamics, ideal gases, the second law of thermodynamics, reversibility and irreversibility, the Carnot cycle and the Kelvin temperature scale, entropy, the steam engine and the refrigerator, applications of thermodynamics to pure substances and to special systems, change of phase, the physics of very low temperatures, the unattainability principle, heterogeneous systems.

PH 244 **Optical Instruments** **(1-2)2**
(PH 204) [PH 206 taken concurrently]

The basic laws of optics and their application to various optical instruments used in industry, such as the microscope, telescope, refractometer, and colorimeter. Considerable emphasis in the laboratory work is placed on the general use of the microscope.

PH 251 **Intermediate Electricity** **(3-3)4**
[MA 205 and PH 205 taken concurrently]

Electric field, potential, Gauss' law, dipoles, Poisson's and Laplace's equations, image problems, dielectric theory, energy, capacitance, force, electric current, d.c. circuits, steady magnetic fields, electromagnetic induction, magnetic properties of matter, L-C-R circuits, analysis of a.c. circuits, and Maxwell's equations.

PH 301 or 302 **Advanced General Physics** **Credits to be arranged**
[Permission of Instructor]

Selected topics in mechanics, heat, sound, electricity, optics, and modern physics presented on an advanced level and emphasiz-

ing the interdependence of higher mathematics, classical physics, and practical concepts of engineering.

PH 311 — **Physical Mechanics** — **(3-0)3**
[PH 212]
Not offered in 1957-58

PH 321 or 322 — **Electronics** — **Gen. Eng. (3-2)4**
[PH 205] — **Others (3-1)3**

The principles of alternating currents as a background for the understanding of electronic circuits. The elements of vacuum and gaseous tube characteristics and of circuits containing such tubes for the purpose of rectification, amplification, and oscillation. Industrial photoelectric relays, time delay relays, and Thymotrol motor controls.

PH 332 — **Theory of Vibrations and Sound** — **(3-0)3**
[MA 301, PH 311]
Not offered in 1957-58

PH 354 — **Electromagnetic Theory** — **(3-0)3**
[MA 302 taken concurrently, PH 206]
Not offered in 1957-58

PH 355 — **Physical Electronics** — **(3-3)4**
[MA 206, PH 206]
Not offered in 1957-58

PH 358 — **Electrical Measurements** — **(2-3)3**
[MA 206, PH 205]
Not offered in 1957-58

PH 362 — **Intermediate Nuclear Physics** — **(3-0)3**
[MA 206, PH 206]
Not offered in 1957-58

PH 401 — **Textile Microscopy** — **(2-3)3**
[PH 205]

Applications of the microscope to textile materials. Methods of sectioning, measurement of cotton immaturity and mercerization, determination of denier of rayon, wool grading, fiber identification, quantitative analysis of fiber mixtures and their practical applications. Some of the more advanced aspects of critical microscopy

which are essential for the best visual work and photographic practice are considered. Some time is devoted to photographic work and the use of polarized light.

PH 402 — **Textile Physics** — (2-2)3

[MA 205, PH 206]

Textile Physics is designed primarily for graduate students but may be taken by seniors who have sufficient knowledge of elementary college physics, microscopy and testing. It deals in an analytical and experimental manner with the principles of advanced physics which have important applications to textile technology. The topics taken up include heat transmission of textile materials; color measurements; calculation of tristimulus values; transformation to dominant wavelength, colorimetric purity, and brightness; measurement of refractive index of fibers; applications of phase microscopy; fluorescent microscopy; use of X-ray diffraction methods to determine crystal orientation and structure of fibers; spectrographic analysis; investigation of mineral elements in textile fibers; and accurate methods of measuring stress, strain, and viscosity.

PH 411-412 — **Quantum Mechanics** — (3-0)(3-0)6

[MA 403-404 taken concurrently, PH 332]

Not offered in 1957-58

PH 421 — **Physical Thermodynamics** — (3-0)3

[MA 302, PH 221]

Not offered in 1957-58

PH 443 — **Spectroscopy** — (2-3)3

Not offered in 1957-58

PH 462 — **Nuclear Physics** — (3-0)3

[MA 403; PH 362; PH 412 taken concurrently]

Not offered in 1957-58

PH 471-472 — **Solid State Physics** — (3-0)(3-3)7

[PH 411-412 taken concurrently]

Not offered in 1957-58

PH 501 or 502 — **The Physics of Color Measurement** — Credits to be arranged

[MA 206, PH 206]

The philosophy and practice of modern colorimetry. Colorimeters, their uses and limitations, spectrophotometers, tristimulus values, dominant wavelength and purity, the "standard observer"

concept, the Munsell system, the Ostwald system, color tolerances, gloss and body color, illuminants, and industrial applications.

Laboratory instruments available consist of brightness testers, monochromatic and trichromatic colorimeters, recording and visual spectrophotometers.

PH 503 or 504 — Spectrographic Methods — (2-2)3
[PH 206]

The theory and application of the spectrograph for the qualitative and quantitative analysis of materials. The Bohr theory, quantum mechanics, atomic models, and the theoretical prediction of line and bend spectra. Special attention is placed in the laboratory on the analysis of elements in paper, leather, and textile samples, and individual problems are assigned to the students.

PH 505 or 506 — X-Ray Diffraction — (2-3)3
[PH 206]

The theory of X-ray diffraction and its application to the structure of matter. Special consideration is given to the taking and interpretation of diffraction data obtained from fibers used in paper and textile technology.

PH 507 or 508 — Electron Microscopy — (1-3)2
[PH 206]

Basic methods in the practice of electron microscopy, including specimen preparation, use and operation of the electron microscope, vacuum techniques, and photography. This work is supplemented with special studies on selected topics.

PH 514 — Statistical Mechanics — (3-0)3
Not offered in 1957-58

PH 515 — Advanced Quantum Mechanics — (3-0)3
Not offered in 1957-58

PH 518 — Relativistic Particle Mechanics — (3-0)3
Not offered in 1957-58

PH 523 — Low Temperature Physics — (3-3)4
Not offered in 1957-58

PH 531 — Acoustics — (3-3)4
Not offered in 1957-58

PH 534 — Crystal Vibrations — (3-3)4
Not offered in 1957-58

PH 553	**Piezoelectricity and Ferroelectricity** Not offered in 1957-58	(3-3)4
PH 562	**Advanced Nuclear Physics** Not offered in 1957-58	(3-0)3
PH 563	**Microwave Spectroscopy** Not offered in 1957-58	(3-3)4
PH 565	**Nuclear Resonance Methods** Not offered in 1957-58	(3-3)4
PH 568	**Neutron Diffraction Analysis** Not offered in 1957-58	(3-0)3
PH 575-576	**Problems in Solid State Physics** Not offered in 1957-58	(3-0)(3-3)7
PH 581	**Information Theory** Not offered in 1957-58	(3-0)3
PH 583	**Relativity Theory** Not offered in 1957-58	(3-0)3
PH 586	**Field Theory** Not offered in 1957-58	(3-0)3
PH 588	**Computers** Not offered in 1957-58	(3-0)3
PH 591 or 592	**Graduate Thesis**	Credits to be arranged

The graduate thesis covers an independent investigation undertaken by the student of a problem which is of interest to a member of the faculty and has the prior approval of the Department Head. The thesis must show ability and originality and must be a clear and systematic written presentation of the results.

PLASTICS

PL 301-302 Introduction to Plastics Technology (3-3)(3-3)8

History, definitions, classes, properties, and applications of plastics. Raw materials and manufacturing processes. Methods of processing plastics materials including compounding, molding, casting, extruding, laminating, fabricating, and finishing. Evaluation and development of typical plastics problems. Laboratory instruction in the processing and fabrication of plastics materials.

PL 401-402 Advanced Plastics Technology (2-3)(2-3)6
[PL 301-302]

Applications of plastics as engineering materials. Product, equipment, and mold design. Correlation of composition, processing, and fabricating with product design and applications. Continuation of laboratory instruction in processing, molding, and fabrication.

PL 403-404 Properties of Polymers (2-3)(2-3)6
[Open to seniors only]

This subject includes the study of important engineering properties of plastics materials; theory of testing; the examination of testing techniques, equipment, and standard ASTM methods for evaluating mechanical, thermal, electrical, and optical properties.

PL 411-412 Plastics Seminar (1-0)(1-0)2
[Open to seniors only]

Informal discussions of topics in, or related to, plastics engineering based on literature study conducted by the individual.

TEXTILES

TE 201-202 — Fiber Technology — (4-0)(3-0)5

A study of the important textile fibers, both natural and man-made. Classifications, origins, marketing, and consumption. Stress is placed on their basic physical and chemical properties and their relationship to processing and utilization.

TE 203 — Textile Fibers — (4-0)3

Similar to TE 201-202, but less detailed. Not open to students in the Textile Technology course.

TE 204 — Yarn Technology — (7-2)5
[EN 205, TE 201]

This subject introduces the fundamental theory and practice of yarn manufacturing by the cotton, woolen, worsted, and filament systems. The aspects covered in TE 204 deal with the theory of yarn manufacture, the manufacture of yarns by the woolen yarn system, and the utilization of reclaimed fibers. The allocation of time is:

TE 204T	Theory	(2-0) 1
TE 204W	Woolen System	(3-2) 3
TE 204R	Reclaimed Fibers	(2-0) 1

TE 206 — Yarn Manufacture — (3-3)4
[TE 203]

Similar to TE 204, but less detailed. Laboratory work consists of demonstrations only. Not open to students in the Textile Technology course.

TE 211-212 — Color — (1-1)(1-1)2

A study of color, value and chroma using the Munsell color system. Several plates painted by the student show the application of color to textiles. These plates include perfected harmony and distribution in patterns illustrating stripes, checks, plaids, and decorative designs. The influence of colors upon one another is stressed.

TE 222 — Cotton Waste Processing — (2-0)2
[TE 204 or 206]

A survey of the methods and machinery used in processing cotton wastes or new cotton handled on waste machinery. The lectures consider the sources of the various wastes, their preparatory treat-

ment, and the manufacturing processes. Laboratory work includes the study of ordinary processing wastes, their treatment in preparation for processing, and experiments on machinery used for yarn manufacture by the waste system. Some time is also devoted to instruction on regular carding, combing, drawing, and roving equipment.

TE 300 **Fabrics** **(2-0)2**
[Permission of Instructor]

This subject is designed to acquaint the student with many of the important fabric types in use today for wearing apparel, home furnishings, and industrial uses. An analytical discussion approach is used so that the student may not only identify the fabrics but also understand the significance of the weave, design, yarns, etc., used.

TE 301-302 **Yarn Technology** **(7-6)(7-6)14**
[TE 204]

A continuation of TE 204. The allocation of time is:

TE 301C	Cotton System	(4-3) 4
TE 301W	Worsted System	(3-3) 3
TE 302C	Cotton System	(3-3) 3
TE 302W	Worsted System	(2-3) 3
TE 302F	Filament System	(2-0) 1

TE 303-304 **Fabric Technology** **(3-4)(3-4)8**
[TE 301-302, taken concurrently]

A study is undertaken of the fundamental theory and practice relating to the design, construction, and analysis of commercial fabrics, regardless of the fibers and/or yarns involved. During this period the basic designs and weaving aspects are covered. The allocation of time is:

TE 303W	Weaving	(1-2) 1½
TE 303D	Design	(2-2) 2½
TE 304W	Weaving	(1-2) 1½
TE 304D	Design	(2-2) 2½

TE 307-308 **Yarn Manufacture** **(3-3)(3-3)8**
[TE 206]

A continuation of TE 206. Not open to students in the Textile Technology course.

TE 309-310 **Fabric Manufacture** **(2-2)(3-3)6**
[TE 307-308, taken concurrently]

An abbreviated version of TE 303-304 and TE 401-402. Laboratory work consists of demonstrations only. Not open to students in the Textile Technology course.

TE 311 **Handloom Weaving** **(0-3)1**

The handloom is used as the means of producing in a minimum amount of time many different fabric constructions, utilizing yarn of different diameters, types and color.

TE 319 **History of Costume and Adaptions** **(1-2)2**

A general coverage of typical costume through the ages from the early Egyptian to the present. The student is expected to make many modern adaptions inspired by period costumes.

TE 323 **Surface Design Fundamentals** **(0-2)1**

Fundamentals of surface design are presented to develop an understanding of various surface patterns and rhythms for pleasing distribution of line and form.

TE 324 **Applied Decorative Design** **(0-2)1**
[TE 323]

Application of the fundamentals learned in TE 323 toward creation of surface patterns for prints and Jacquards.

TE 327-328 **Elements of Textile Manufacture** **(2-2)(2-2)6**

The elements of fiber preparation, yarn manufacture by all the common systems, weaving, and knitting are presented in a survey fashion. Laboratory consists of demonstrations only.

TE 352 **Fabric Draping** **(0-3)1**

The application of fabric to form for the purpose of understanding fully the use and limitations of various fabrics used in garments.

TE 401-402 **Fabric Technology** **(5-7)(5-7)12**
[TE 304]

A continuation of TE 303-304. The allocation of time is:

TE 401W	Weaving	(1-2) 1½
TE 401D	Design	(3-4) 3½
TE 401C	Color	(1-1) 1
TE 402W	Weaving	(1-2) 1½
TE 402D	Design	(2-3) 2½
TE 402K	Knitting	(2-2) 2

TE 403-404 **Textile Evaluation** **(2-2)(2-2)6**
[CH 102, EN 352, PH 206]

This subject is designed to provide a foundation for more advanced work in testing, and is of sufficient breadth to benefit those students whose main need is an understanding and appreciation of

the scope of testing and evaluation in the textile industry. The subject matter covers an applied approach to the statistical treatment of experimental data, and the basic mechanical or physical, chemical, and optical tools and techniques available to the industry for product control, development, and evaluation. Primary emphasis is placed upon an understanding of the principles involved and an integration of the various phases of textile testing into a unified whole.

TE 405-406 **Finishing Technology** (4-2)(0-4)6
[CH 302; TE 304 or 310]

Lectures and pilot plant laboratory work in all major physical and chemical operations necessary for the conversion into the finished state of all fabrics commonly used, regardless of fiber content. The allocation of time is:

TE 405C	Cotton System	(2-1) 2
TE 405W	Woolen and Worsted System	(2-1) 2
TE 406C	Cotton System	(0-2) 1
TE 406W	Woolen and Worsted System	(0-2) 1

TE 407 **Knitting** (2-3)3

Similar to TE 419, but with less laboratory work.

TE 408 **Cotton and Synthetic Finishing** (3-3)4

Similar to TE 421, but stressing the chemical, rather than the physical, aspects.

TE 409 **Woolen and Worsted Finishing** (3-3)4
[CH 102 or 104]

An abbreviated version of TE 423-424.

TE 411-412 **Jacquard Design and Weaving** (1-2)(1-2)4
[Permission of Instructor]

Weaving on the Jacquard loom and the various tie-ups in common use. Instruction includes the sketching of original designs as applied to particular fabrics. The student is taught to transfer his original sketch to cross-section design paper, to choose the proper weave for both the background and foreground, to cut cards and lace, and to weave the fabric.

TE 413 or 414 **Jacquard Design** (0-2)1
[Permission of Instructor]

The student is taught to transfer a given motif to cross-section paper, to choose the proper weave for the background and the fore-

ground, and complete a Jacquard design. A sufficient number of cards are cut and laced to enable the student to appreciate the complete operation from the motif to the loom.

TE 415 Woolen and Worsted Mill Organization (4-0)4

A recapitulation of the routine covered in previous wool textile manufacturing subjects. Mill layouts are organized to make definite yardages of specific fabrics using modern machinery by both the woolen and worsted systems of manufacture.

TE 417 Cotton Mill Organization (4-0)4

This subject correlates all of the work on cotton manufacturing. Starting with a study of actual mill organizations the class is carried forward to problems in developing new organizations for specific types of products. The adaptations for long draft and for the handling of staple fibers are carefully covered. Calculations are made for the machinery necessary to keep plants in balance with some consideration of the best arrangements for economical handling.

TE 419 Knitting (2-5)4
[Permission of Instructor]

A broad survey of the important types of knitting. Considerable stress is placed on the various stitches and the characteristics of fabrics from each. Starting with flat machines, the work advances through small ribbers, automatic hosiery machines, full-fashioned hosiery machines, underwear machines and warp knitters. The production, design, and analysis of knit fabrics and the classifications and routines for manufacture of hosiery and underwear are included.

TE 421 Cotton and Synthetic Finishing (3-3)4

All the major physical and chemical operations necessary for the conversion into the finished state of staple gray cotton and synthetic fabrics are considered. In addition to inspection, singeing, desizing, padding, drying, calendering, curing, etc., the preliminary wet processing operations through dyeing are illustrated. Among the types of finishes employed are those of starching, softening, repelling, stabilizing, decating, etc., as well as the thermoplastic and thermosetting resins. The physical, rather than the chemical, aspects are stressed.

TE 422 Advanced Textile Design and Analysis (2-1)2
[Permission of Instructor]

The first half of the semester is devoted to the study of Leavers Lace including history, manufacture, finishing, a detailed study of the Leavers machine, and the basic principles of lace design and

drafting. The second half of the semester covers a study of embroideries and rugs. Schiffli embroidery includes the Schiffli machine, basic principles of Schiffli design, manufacturing, finishing, and types and end uses of embroidery. Rugs include a study of the principles of construction and the analyses of Chenille, Wilton, Brussels, Tapestry, Velvet and Axminster carpets.

TE 423-424 Woolen and Worsted Finishing (2-3)(2-3)6
[CH 102]

A comprehensive introduction and orientation to the physical, rather than chemical, aspects of finishing including burling and mending, fulling, washing and speck dyeing, carbonizing, gigging, napping, steaming, singeing, crabbing, brushing, shearing, and pressing.

TE 426 Advanced Knitting (2-5)4
[TE 419]

This is an advanced subject for students who are specializing in knitting. With the approval of the department head, the student may select a particular field from the various sections of the knitting industry and concentrate on its problems.

TE 427-428 Properties and Applications of Synthetic Fibers (3-0)(3-0)6

Much of the time will be spent on consideration of the fundamental properties of man-made fibers in relation to one another and to the behaviors of the finished textile resulting from these basic properties and the geometry imposed upon the fibers in the textile. To make the material more useful, comparisons are made with natural fibers and their textiles. Recent advances in the manufacture and study of fibers will be discussed.

TE 431 or 432 Advanced Weaving (2-3)3
[Permission of Instructor]

Advanced work on the Crompton & Knowles looms, including the overhead multiplier, the filling mixer, and the tri-color automatic loom. Advanced work on the dobby looms, including Leno and Terry attachments. Other advanced areas such as Jacquard heads, harness mounting problems, and carpet weaving are also covered.

TE 435 Woolen and Worsted Design (1-2)2

Analysis and construction of woolen and worsted fabrics.

TE 437 Weaving Laboratory (0-3)1

Application of theories learned in textile manufacturing classes.

TE 444 **Jacquard Design** **(1-2)2**

Instruction includes work on original sketch, transfer to cross-section paper, and indication of weave for background and foreground, in order to cut cards and lace for the Jacquard loom.

TE 445-446 **Textile Finishing** **(4-2)(2-4)8**
[CH 202, 356, 364; TE 328]

Same as TE 405-406 with the major extension into the chemical rather than the engineering phases. The second semester is devoted to pilot- and semi-plant laboratory practice. The student is the major participant in the progression and conversion in the laboratory with the emphasis once again on the chemical processes. The allocation of time is:

TE 445C	Cotton	(2-1) 2
TE 445W	Woolen and Worsted	(2-1) 2
TE 446C	Cotton	(1-2) 2
TE 446W	Woolen and Worsted	(1-2) 2

TE 501 or 502 **Methods of Research** **(2-0)2**

A seminar to familiarize the student with the philosophy and methods of research, current problems in textile research and the further use of textile literature.

TE 590-591 **Thesis Research** **Credits to be arranged**

Other subjects pertaining to textiles are listed under Chemistry, Engineering, and Physics. They are:

CH 302	Introduction to Textile Chemistry	(1-3) 2
CH 311	Textile Quantitative Analysis	(2-4) 3
CH 355	Chemistry and Physics of Fibers	(2-3) 3
CH 356	Chemistry of Fiber Purification	(2-3) 3
CH 364	Textile Colloid Chemistry	(4-0) 4
CH 401	Introduction to Textile Chemistry	(1-3) 2
CH 408	Advanced Studies in Chemistry	Credits to be arranged
CH 422	Chemical Textile Testing	(2-3) 3
CH 453	Theory of Dyeing	(3-4) 4
CH 454	Industrial Dyeing and Printing	(2-8) 4
CH 461	Microbiology	(1-3) 2
CH 491	Textile Chemistry Literature Seminar	(2-0) 2
CH 501	Color Measurement for Textile Chemists	(1-3) 2

CH 505	Physical Chemistry of Dyeing	(2-3) 3
CH 512	The Physical Chemistry of Surface-active Agents	(1-3) 2
CH 551 or 552	Textile Testing Problems	(1-3) 2
CH 553-554	Evaluation of Finishing Agents	Credits to be arranged
CH 555-556	Textile Chemistry Seminar	(2-0) (2-0)4
CH 559	Instrumental Methods in Textile Research	(1-2) 2
EN 304	Instrumentation for Textile Processing	(2-2) 3
EN 430	Engineering Design of Textile Structures	(3-0) 3
EN 431 or 432	Advanced Physical Textile Testing	(2-3) 3
PH 401	Textile Microscopy	(2-3) 3
PH 402	Textile Physics	(2-2) 3

DEGREES CONFERRED IN 1956

Bachelor of Science

Edward Jerome Adler
†Richard Bruce Aldrich
David Ladd Bagshaw
Anil Banker
Francis James Carolan
Padamshi Khimji Chheda
Donald Preston Coates
†Harold Nissen Cotton
Robert Emmett Crowe
Jean Ann Cryan
Marcella Stasia Czekanski
James Tobin Doyle
Wallace Jay Filler
William Frederick Frei
†Gerald Thomas Gallagher
Frank Holland Gentle, Jr.
Paul Leo Gormley, Jr.
Norman G. Greene
†Curtis Arthur Guild, Jr.
†David Ernest Hanlon
Francis Joseph Hogan, Jr.
John Edward Jouret
Dennis Stanley Kaplan
Harvey Kaye
†James Michael Keohane
Fred E. Klimpl
James Allison Knox, Jr.
Edward Robert Koza
George Leon Landry
Paul Arthur Law
Paul E. Leipzig
Frances Therese Libbey
Edward Allen Long
Ellsworth G. Mann, Jr.
Donald M. McCord
John James McLaughlin, Jr.
Paul John Moser
Binod J. Nair
Normand Bernard Ouellette
David M. Peck
William Henry Pedrick
David Bruce Perlstein
Paul Gerard Perra
Donald Nichols Perrott
Francis Anthony Raudelunas
Elliot Remler
Michael David Sands
Eugene Phillip Schwartz
†Raymond Patrick Sharkey
David Henry Shay
Jay Arnold Sherman
Leonard R. Sheroff
Edgar Warren Slatkin
Raymond William Tabloski
Owen Craig Tierney
James Francis Walsh
Laurence Brabrook Walsh
Eugene Francis Welch, Jr.
John Robert White

Bachelor of Science with Honors

*James Thomas Davies
*Alan Albert Denio
*Carol Ann Dunn
*Richard Francis Hoyle
Salim Meir Ibrahim
*Richard Eugene LaFrance
*†Richard Leroy Peckham
*†Chester John Petkiewicz

Bachelor of Science with High Honors

*Philip Shepard Lamprey
*Francis Leo McKone
*Frederick Woods Obear
*Bernard Shapiro

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*Tau Epsilon Sigma *(Textile Scholastic Society)*
†Commissioned Second Lieutenant in the United States Air Force Reserve

Master of Science

Gordon Lysle Axon — *Textile Chemistry*
B.S., Lowell Technological Institute, 1952

Selim Benardete — *Textile Engineering*
B.S., Robert College, 1949

Robert Thomas Cassidy — *Textile Engineering*
B.S., Lowell Technological Institute, 1954

Charles Koulias Chiklis — *Textile Chemistry*
B.S., Lowell Technological Institute, 1955

Arthur Whittier Claridge — *Textile Engineering*
B.S., Lowell Technological Institute, 1952

Edward James Collins — *Textile Engineering*
B.S., Lowell Technological Institute, 1954

*Charles David Flamand — *Textile Chemistry*
B.S., Lowell Technological Institute, 1953

Walter Gonet — *Textile Chemistry*
B.S., New Bedford Institute of Textiles and Technology, 1952

Ilhan Kinaci — *Textile Engineering*
B.S., Robert College, 1954

Fevzi Halil Ozbilen — *Textile Engineering*
B.S., Robert College, 1954

Joseph Alexander Roux — *Textile Chemistry*
B.S., Lowell Technological Institute, 1952

Sanae Sakaguchi — *Textile Chemistry*
B.E., Kyoto Technical University, 1949

Jayant K. Sanghrajka — *Textile Chemistry*
B.S., Lowell Technological Institute, 1955

Henry Myron Szczepanik — *Textile Chemistry*
B.S., Lowell Technological Institute, 1952

Edward Keller Yellman — *Textile Engineering*
Captain, United States Army
B.S., U.S. Military Academy, 1949

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*Tau Epsilon Sigma *(Textile Scholastic Society)*

DEGREES CONFERRED AS OF JANUARY 30, 1957

Bachelor of Science

James Allan Condon
Normand Bernard Dufour
Pierre Joseph Jacques
Robert Thomas Nagle

Master of Science

Salim M. Ibrahim
Maung Maung Than

HONORARY DEGREES

Doctor of Science

Henry Horton Armsby
Chief for Engineering Education, United States Office of Education

Robert Cutler
Chairman, Board of Directors, Old Colony Trust Company

Barnett David Gordon
President, M. K. M. Knitting Mills, Inc.

Edward Benno Hanify
Attorney, Ropes, Gray, Best, Coolidge and Rugg

Ralph Lowell
President, Boston Safe Deposit and Trust Company

SERIES 61. NO. 1.
CURRICULUM BULLETIN

BULLETIN

of the

Lowell Technological Institute of Massachusetts

LOWELL, MASS.

1957-1958

Entered August 26, 1902, at Lowell, Mass., as second-class matter
under act of Congress of July 16, 1894

Textile and Colonial Avenue

EVENING DIVISION

Publication of this Document Approved by George J. Cronin, State Purchasing Agent

rm ED-LTI-6. 8m-7-57-920687

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CALENDAR—1957-1958

First Semester

September 9, 10, 17, 1957, 7-8:30 P.M.	Registration
September 23, 1957, Monday	Classes begin
November 11, 1957, Monday	Veterans Day, Holiday
November 27, 28, 29, 1957, Wednesday, Thursday and Friday	Thanksgiving Recess
December 23, 1957, Monday	Christmas Recess begins
January 6, 1958, Monday	Classes resume
January 17, 1958, Friday	End of First Semester

Second Semester

January 14, 15, 16, 1958, 7-8:30 P.M.	Registration
January 27, 1958, Monday	Classes begin
March 31, 1958, Monday	Easter Recess begins
April 7, 1958, Monday	Classes resume
May 16, 1958, Friday	End of Second Semester

FACULTY

CHEMISTRY

Prof. George R. Griffin, B.S., M.A., Ph.D., *Chairman of Division*
Prof. Allen Scattergood, A.B., Ph.D.
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Assoc. Prof. Roy Kuffner, B.S., Ph.D.
Asst. Prof. Charles A. Everett, B.T.C.
Asst. Prof. Vasilis Lavrakas, B.S., M.S.
Asst. Prof. Walter J. Lisien, B.T.C.
Asst. Prof. Robert J. Peirent, B.S., M.S.
Mr. Ray E. MacAusland
Mr. Robert Morrison, B.S.

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General Engineering, Electricity, and Electronics

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Assoc. Prof. Maurice E. Gelinas, S.B., A.M.
Asst. Prof. J. Arthur Ainsworth, B.S., M.S.
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Mr. Charles Sadlier, B.S.
Mr. Kenneth Stewart, B.S., M.S.
Mr. Sidney E. Stirk, B.S.
Mr. Charles Walker, B.S.
Mr. Chester Whitney

Leather Engineering

Prof. Albert E. Chouinard, B.S., M.S., Ph.D., *in charge*
Mr. William Dooley, B.S.

Paper Engineering

Prof. John Lewis, B.S., M.S., *in charge*
Asst. Prof. Edward Engel, B.S., M.S.
Asst. Prof. Norwood H. Keeney, B.S., M.S.
Mr. Charles Higgins, B.S.

Plastics Engineering

Prof. Russell W. Ehlers, B.S., M.S., Ph.D., *in charge*
Mr. Raymond Normandin, A.B., M.S.
Mr. A. C. Walker, Jr., B.S., M.S.

Rubber Engineering

Dr. Juan C. Montermoso

GENERAL STUDIES

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Mrs. William G. Chace
Miss Margaret Donohoe

Mrs. William E. Kaknes
Mrs. William R. Kiernan
Mrs. Margaret A. Moriarty
Miss Antoinette W. Nault
Mr. Leo Panas
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Mr. John F. Vaughan

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Mr. Arthur F. Haley, Jr., B.S., M.Ed.
Mr. Francis K. Neilon, B.A., Ed.M.

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Asst. Prof. Thomas A. Malloy, A.B., M.A.
Mr. Wilfrid J. Brodeur
Miss Barbara Browne, A.B.
Mr. Arthur Egerton, Jr.
Mr. George C. Hedrick
Mr. George Toscano, B.S.

TEXTILE MANUFACTURING

Prof. Jacob K. Frederick, Jr., B.S., *Chairman of Division*

DESIGN, WEAVING, AND KNITTING

Prof. Vittoria Rosatto, B.S., *in charge*
Assoc. Prof. Edward L. Golec, B.S.
Assoc. Prof. Nathaniel E. Jones
Assoc. Prof. John L. Merrill, B.T.E.
Asst. Prof. Albert T. Woidzik, B.S.
Mrs. Lucy R. Weinbeck, B.T.E.

TEXTILE FINISHING

Prof. John J. McDonald, B.T.C., M.S., *in charge*
Assoc. Prof. Winford S. Nowell, B.M.E.

COTTON AND STAPLE SYNTHETIC YARNS

Assoc. Prof. John A. Goodwin, B.T.E., M.S., *in charge*
Asst. Prof. Clarence J. Pope, B.S., M.S.
Mr. Kenneth S. Merrill, B.S.

WOOL AND STAPLE SYNTHETIC YARNS

Asst. Prof. Russell L. Brown, B.S., *in charge*
Asst. Prof. J. Frederic Burtt, B.T.E.

GENERAL INFORMATION

Registration

Students may register by filling out the necessary forms and paying fees before attending classes. Registration is held on the dates indicated in the calendar.

Classes are held on Monday, Tuesday, Wednesday, Thursday and Friday evenings each week, usually from 7:00 P.M. to 9:00 P.M., although other hours are sometimes required in particular subjects. Classes for those students taking courses toward an Associate Degree will be held from 7:00 P.M. to 9:30 P.M.

The scheduled nights for the various subjects in the following pages are tentative and may be altered in a few cases.

A student must have reached his sixteenth birthday before registering in the Evening Division, unless he has special permission from the Director of the Evening Division.

Late Registration

No new registrations or class changes will be accepted after the first two weeks of classes have been held.

Registration Fee

A registration fee of one dollar per semester is required of all students, in addition to tuition and other charges.

Employees of Lowell Technological Institute

Employees of the Lowell Technological Institute and its Research Foundation are exempt from all tuition charges.

All Tuition and fees must be paid in full at the time of registration.

Laboratory Fees

Students electing any subject that requires laboratory work must pay a laboratory fee of $20 per semester in addition to their tuition. These fees are to cover supplies and normal breakage. Any excessive breakage will be billed directly to the student and must be paid before credit can be obtained. No portion of these laboratory fees will be returned except as provided in the section on refunds. These laboratory fee requirements apply to all students whether they are residents or non-residents of Lowell and whether they are studying for credit or non-credit.

Refunds

Students dropping out of a class any time before the end of the first two weeks may obtain a refund of 80% of their tuition and fees. Students dropping out of a class any time from the second to the fifth week may be refunded 50% of their tuition and fees. There are no refunds after the fifth week of classes. A student must file an application for refund before one can be made. The registration fee of one dollar will not be returned in any case unless the class is cancelled.

Size of Class

No first-year subject will be given unless at least 15 students register for it. In a few instances, more than that number are required. Advanced subjects will usually, but not necessarily, be given, regardless of number.

Veterans

All veterans entitled to educational benefits under the law should secure from the V. A. Office, a certificate of eligibility before registering.

Books and Supplies

Students must provide their own books, paper, and drawing materials, and pay for any breakage or damage of school equipment that they may cause.

Student supplies will be sold by the school cooperative store each school evening from 6:45 P.M. to 8:15 P.M.

Inclement Weather

Due to difficulties in notifying in time students and instructors who reside at a distance, evening school will not be cancelled for reasons of weather at any time.

Credits

Subjects considered of college level are indicated in the subject description and credit hours are assigned to them. A high-school diploma is a prerequisite for all college-level courses.

Grading System

The following system of grading is used:

A	90 - 100	Excellent
B	80 - 89	Good
C	70 - 79	Fair
D	60 - 69	Lowest Passing Grade
F	50 - 59	Failure
W	Withdrawn	
X	Dropped	

Please note that no student will be permitted to graduate from the Associate Degree courses with less than a "C" average.

Information

Address correspondence to:

Director of Evening Division
Lowell Technological Institute
Lowell, Massachusetts

ASSOCIATE DEGREE
GENERAL INFORMATION

Entrance Requirements

For subjects taken toward an Associate Degree in Engineering, the requirement is graduation from a recognized high school or equivalent study or achievement, including one year of algebra.

College Credit

All courses offered in the associate degree program are given on the undergraduate college level and carry college credit hours as indicated in the course descriptions. They are acceptable for credit in the day division of the Lowell Technological Institute for comparable courses.

Conditioned Students

Applicants for the Associate Degree in Engineering who do not meet the full equirements for admission as regular students may, at the discretion of the Committee on Admissions, be admitted as conditioned students provided the econdary-school work completed embraces one unit of algebra.

A conditioned student whose scholarship is satisfactory but who has not removed his conditions within the time specified by the Committee on Admissions nay be permitted to continue with his program of studies. However, on the ompletion of the chosen four-year curriculum he will receive a diploma rather han the Degree of Associate in Engineering.

Students who wish to register for single subjects in the engineering curriculum an do so provided they have the necessary prerequisites.

Tuition for Subjects Carrying College Credit

All students working toward an Associate Degree as well as those students aking other subjects carrying college credit will be charged $9 per credit to a maximum of $25 per subject. However, college-level subjects may be taken without college credit at the rate charged for non-credit subjects. A student annot take a college-credit subject at the regular rates and then apply for credit at the end of the term.

Tuition for Associate Degree Courses Only

Those students taking courses toward an Associate Degree will be charged ne regular credit fee of $9 per credit up to a maximum of $25. The tuition ee for a class meeting 2½ hours per week is, therefore, $22.50 per semester r $45.00 a year.

All tuition and fees must be paid in full at the time of registration.

Attendance

Students in college-credit and Associate Degree Courses must attend 80% of ll classes. Four unexplained absences in a row will result in the student's being utomatically dropped from the rolls.

ASSOCIATE DEGREE

First Semester Subjects (Sept. - Jan.)

7 - 9:30 P.M.

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
C-1	General Chemistry	To Be Arranged	None
C-15	General Colloid Chemistry	Not Offered 1957-58	C-6
C-11-13	High Polymer Lab.	To Be Arranged	C-10
C-5	Organic Chemistry	To Be Arranged	C-2
C-9	Organic High Polymer Chemistry	Not Offered 1957-58	C-8
C-7	Physical Chemistry	Not Offered 1957-58	C-4, M-6
C-3	Qualitative Analysis	To Be Arranged	C-2
E-1	A.C. Machinery Lab.	Not Offered 1957-58	E-6
E-3	Advanced Electronic Lab. I	Not Offered 1957-58	E-113, 115 Concurrentl
E-5	Algebra	To Be Arranged	E-7
E-11	Analytical Geometry and	E-11, 13 Taken Concurrently	E-11
E-13	Differential Calculus	To Be Arranged	E-11
E-15	Applied Leather Analysis	Not Offered 1957-58	C-6
E-19	Applied Mechanics	To Be Arranged	E-114, E-99
E-29	D.C. Machinery	To Be Arranged	E-33
E-31	D.C. Machinery Lab.	To Be Arranged	E-29
E-33	D.C. Theory	To Be Arranged	E-11
E-37	Electronics for Industry	Not Offered 1957-58	E-114, E-29
E-39	Electronic Physics	To Be Arranged	E-90
E-41	Electron Tubes & Circuits	To Be Arranged	E-33, E-10
E-43	Electrical Measurements	To Be Arranged	E-52, E-33, 1
E-45	Engineering Drawing	To Be Arranged	None
E-53	Heat Engineering	Not Offered 1957-58	E-99, E-90
E-55	Job Evaluation and Merit Rating	To Be Arranged	None
E-57	Leather Technology	Not Offered 1957-58	C-6
E-59	Leather Technology	Not Offered 1957-58	E-56
E-67	Machine Design	Not Offered 1957-58	E-123, E-10
E-69	Machine Drawing	To Be Arranged	E-38
E-79	Mechanical Engineering Lab.	Not Offered 1957-58	E-46, E-53
E-81	Mechanism	To Be Arranged	E-68, E-69
E-87	Paper Technology	Not Offered 1957-58	C-6
E-89	Paper Technology	Not Offered 1957-58	E-84
E-91	Paper Manufacturing — Testing and Analysis	Not Offered 1957-58	C-6
E-93	Paper Manufacturing — Testing and Analysis	Not Offered 1957-58	E-80
E-95	Physical Testing of Leather	Not Offered 1957-58	E-54
E-99	Physics	To Be Arranged	E-97
E-103	Plastic Technology	Not Offered 1957-58	C-6
E-105	Plastic Technology	Not Offered 1957-58	E-92
E-115	Communication Engineering	Not Offered 1957-58	E-36
E-117	Rubber Technology	To Be Arranged	C-6
E-119	Rubber Technology	Not Offered 1957-58	E-10
E-123	Strength of Materials	To Be Arranged	E-18, E-19, E-52
E-127	Time Study	Not Offered 1957-58	None

ASSOCIATE DEGREE

SECOND SEMESTER SUBJECTS (JAN. - MAY)

7 - 9:30 P.M.

UMBER	SUBJECT	EVENINGS	PRE-REQUISITE
-2	General Chemistry	To Be Arranged	C-1
-16	General Colloid Chemistry	Not Offered 1957-58	C-15
-12-14	High Polymer Lab.	Not Offered 1957-58	C-11
-6	Organic Chemistry	To Be Arranged	C-5
-8	Physical Chemistry	Not Offered 1957-58	C-7
-10	Physical Chemistry of High Polymers	Not Offered 1957-58	C-9
-4	Quantitative Analysis	To Be Arranged	C-3
-2	Advanced Electronic Lab. II	Not Offered 1957-58	E-40 Concurrently
-6	A.C. Machinery	To Be Arranged	E-10
-8	A.C. Machinery Lab.	To Be Arranged	E-6
-10	A.C. Theory	To Be Arranged	E-33
-18	Applied Mechanics	To Be Arranged	E-99, E-14
-32	Electronics for Industry Lab.	Not Offered 1957-58	E-37
-34	Electronic Lab.	To Be Arranged	E-36 Concurrently
-36	Electron Tubes and Circuits	To Be Arranged	E-41
-38	Engineering Drawing	To Be Arranged	E-45
-40	Frequency Modulation and Television	Not Offered 1957-58	E-113, E-115
-46	Heat Engineering	Not Offered 1957-58	E-99, E-90
-48	Hydraulics	To Be Arranged	E-18, E-19
-52	Integral Calculus	To Be Arranged	E-13
-54	Leather Histology	Not Offered 1957-58	E-15
56	Leather Technology	Not Offered 1957-58	E-57
58	Leather Technology	Not Offered 1957-58	E-59
66	Machine Design	Not Offered 1957-58	E-108, E-123
68	Machine Drawing	To Be Arranged	E-38, E-45
78	Mechanical Engineering Lab.	Not Offered 1957-58	E-46, E-53
80	Paper Manufacturing — Testing and Analysis	Not Offered 1957-58	E-91
82	Paper Manufacturing — Testing and Analysis	Not Offered 1957-58	E-93
84	Paper Technology	Not Offered 1957-58	E-89
90	Physics	To Be Arranged	E-99
92	Plastic Technology	Not Offered 1957-58	E-103
94	Plastic Technology	Not Offered 1957-58	E-105
96	Principles of Production and Planning	Not Offered 1957-58	None
100	Research Problems in Leather	Not Offered 1957-58	E-95
102	Rubber Technology	To Be Arranged	E-117
104	Rubber Technology	Not Offered 1957-58	E-119
106	Semi-Conductors & Transistors	To Be Arranged	E-33, E-39
108	Strength of Materials	To Be Arranged	E-18, 19, E-52
112	Transmission and Distribution Theory	Not Offered 1957-58	E-6
114	Trigonometry	To Be Arranged	E-5
118	Work Simplification	To Be Arranged	None

CHEMISTRY

Leading to the Degree of Associate in Science

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-99	Physics I	2½	E-90	Physics II	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chem. Lab.	2½
		7½			7½

THIRD YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-11	Analytical Geometry	2½	E-52	Integral Calculus	2½
E-13	Differential Calculus		C-6	Organic Chemistry	2½
C-5	Organic Chemistry	2½	C-6L	Organic Chemistry Lab.	2½
C-5L	Organic Chemistry Lab.	2½			
		7½			7½

FOURTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
C-7L	Physical Chemistry Lab.	2½	C-8L	Physical Chemistry Lab.	2½
	Elective	2½		Elective	2½
		7½			7½

ELECTRICAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
ourse No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
-5	Algebra	2½	E-114	Trigonometry	2½
-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

11	Analytical Geometry	2½			
13	Differential Calculus		E-52	Integral Calculus	2½
33	D-C Theory	2½	E-10	A-C Theory	2½
19	Applied Mechanics I	2½	E-18	Applied Mechanics II	2½
		7½			7½

THIRD YEAR

123	Strength of Materials	2½	E-108	Strength of Materials	2½
29	D-C Machinery	2½	E-6	A-C Machinery	2½
31	D-C Machinery Lab.	2½	E-8	A-C Machinery Lab. I	2½
		7½			7½

FOURTH YEAR

37	Electronics for Industry	2½	E-112	Transmission Theory	2½
53	Heat Engineering	2½	E-46	Heat Engineering	2½
E	A-C Machinery Lab. II	2½	E-32	Electronics for Industry Lab.	2½
		7½			7½

ELECTRONIC ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester

Course No.	COURSE	Class Hours
E-5	Algebra	2½
E-45	Engineering Drawing	2½
E-99	Physics I	2½
		7½

Second Semester

Course No.	COURSE	Class Hours
E-114	Trigonometry	2½
E-38	Engineering Drawing	2½
E-90	Physics II	2½
		7½

SECOND YEAR

Course No.	COURSE	Class Hours
E-11	Analytical Geometry	2½
E-13	Differential Calculus	
E-33	D-C Theory	2½
E-39	Electronic Physics	2½
		7½

Course No.	COURSE	Class Hours
E-52	Integral Calculus	2½
E-10	A-C Theory	2½
E-106	Semi-Conductors and Transistors	2½
		7½

THIRD YEAR

Course No.	COURSE	Class Hours
E-41	Electron Tubes and Circuits I	5
E-43	Electrical Measurements	2½
		7½

Course No.	COURSE	Class Hours
E-36	Electron Tubes and Circuits II	5
E-34	Electronic Lab.	2½
		7½

FOURTH YEAR

Course No.	COURSE	Class Hours
E-27A	Communication Engineering	5
E-3	Advanced Electronic Lab. I	2½
		7½

Course No.	COURSE	Class Hours
E-40	Frequency Modulation and Television	5
E-2	Advanced Electronic Lab. II	2½
		7½

INDUSTRIAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
-5	Algebra	2½	E-114	Trigonometry	2½
-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

-11	Analytical Geometry	2½			
-13	Differential Calculus		E-52	Integral Calculus	2½
-19	Applied Mechanics	2½	E-18	Applied Mechanics	2½
-69	Machine Drawing	2½	E-68	Machine Drawing	2½
		7½			7½

THIRD YEAR

-123	Strength of Materials	2½	E-108	Strength of Materials	2½
-55	Job Evaluation and Merit Rating	2½	E-118	Work Simplification	2½
53	Heat Engineering	2½	E-46	Heat Engineering	2½
		7½			7½

FOURTH YEAR

67	Machine Design	2½	E-66	Machine Design	2½
127	Time Study	2½	E-96	Principles of Production Planning	2½
	Engineering Elective	2½		Engineering Elective	2½
		7½			7½

LEATHER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C1	General Chemistry	2½	C2	General Chemistry	2½
C1-L	General Chemistry Lab.	2½	C2-L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics	2½	E-99	Physics	2½
C3	Qualitative Chemistry	2½	C4	Quantitative Chemistry	2½
C3-L	Qualitative Chemistry Lab.	2½	C4-L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry	2½	E-52	Integral Calculus	2½
E-13	Differential Calculus		C6	Organic Chemistry	2½
C5	Organic Chemistry	2½	C6-L	Organic Chemistry Lab.	2½
C5-L	Organic Chemistry Lab.	2½			
		7½			7½

FOURTH YEAR

C7	Physical Chemistry	2½	C8	Physical Chemistry	2½
E-15	Applied Leather Analysis	2½	E-54	Leather Histology	2½
E-57	Leather Technology	2½	E-56	Leather Technology	2½
		7½			7½

FIFTH YEAR

E-59	Leather Technology	2½	E-58	Leather Technology	2½
E-95	Physical Testing of Leather	2½	E-100	Research Problems in Leather	2½
		5			5

MECHANICAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
E-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
E-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

E-11	Analytical Geometry	2½			
E-13	Differential Calculus		E-52	Integral Calculus	2½
E-69	Machine Drawing	2½	E-68	Machine Drawing	2½
E-19	Applied Mechanics	2½	E-18	Applied Mechanics	2½
		7½			7½

THIRD YEAR

E-123	Strength of Materials	2½	E-108	Strength of Materials	2½
E-81	Mechanism	2½	E-48	Hydraulics	2½
E-53	Heat Engineering	2½	E-46	Heat Engineering	2½
		7½			7½

FOURTH YEAR

E-67	Machine Design	2½	E-66	Machine Design	2½
E-79	Mechanical Engineering Lab.	2½	E-78	Mechanical Engineering Lab.	2½
	Engineering Elective	2½		Engineering Elective	2½
		7½			7½

PAPER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	Course	Class Hours	Second Semester Course No.	Course	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C1	General Chemistry	2½	C2	General Chemistry	2½
C1-L	General Chemistry Lab.	2½	C2-L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-99	Physics	2½	E-90	Physics	2½
C3	Qualitative Chemistry	2½	C4	Quantitative Chemistry	2½
C3-L	Qualitative Chemistry Lab.	2½	C4-L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-11	Analytical Chemistry	2½	E-52	Integral Calculus	2½
E-13	Differential Calculus		C6	Organic Chemistry	2½
C5	Organic Chemistry	2½	C6-L	Organic Chemistry Lab.	2½
C5-L	Organic Chemistry Lab.	2½			
		7½			7½

FOURTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
C7	Physical Chemistry	2½	C8	Physical Chemistry	2½
E-87	Paper Technology	2½	E-84	Paper Technology	2½
E-91	Paper Manufacturing—Testing and Analysis	2½	E-80	Paper Manufacturing—Testing and Analysis	2½
		7½			7½

FIFTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-89	Paper Technology	2½	E-86	Paper Technology	2½
E-93	Paper Manufacturing—Testing and Analysis	2½	E-82	Paper Manufacturing—Testing and Analysis	2½
C15	General Colloid Chemistry	2½	C16	General Colloid Chemistry	2½
		7½			7½

PLASTICS ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C1	General Chemistry	2½	C2	General Chemistry	2½
C1-L	General Chemistry Lab.	2½	C2-L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics	2½	E-90	Physics	2½
C3	Qualitative Chemistry	2½	C4	Quantitative Chemistry	2½
C3-L	Qualitative Lab.	2½	C4-L	Quantitative Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry	2½	E-52	Integral Calculus	2½
E-13	Differential Calculus		C6	Organic Chemistry	2½
C5	Organic Chemistry	2½	C6-L	Organic Chemistry Lab.	2½
C5-L	Organic Chemistry Lab.	2½			
		7½			7½

FOURTH YEAR

C7	Physical Chemistry	2½	C8	Physical Chemistry	2½
C9	Organic High Polymer Chemistry	2½	C10	Physical Chemistry of High Polymers	2½
E-103	Plastic Technology	2½	E-92	Plastic Technology	2½
		7½			7½

FIFTH YEAR

C11	High Polymer Lab.	2½	C12	High Polymer Lab.	2½
E-105	Plastic Technology	2½	E-94	Plastic Technology	2½
		5			5

RUBBER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C1	General Chemistry	2½	C2	General Chemistry	2½
C1-L	General Chemistry Lab.	2½	C2-L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-99	Physics	2½	E-90	Physics	2½
C3	Qualitative Chemistry	2½	C4	Quantitative Chemistry	2½
C3-L	Qualitative Lab.	2½	C4-L	Quantitative Lab.	2½
		7½			7½

THIRD YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-11	Analytical Geometry	2½	E-52	Integral Calculus	2½
E-13	Differential Calculus		C6	Organic Chemistry	2½
C5	Organic Chemistry	2½	C6-L	Organic Chemistry Lab.	2½
C5-L	Organic Chemistry Lab.	2½			
		7½			7½

FOURTH YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
C7	Physical Chemistry	2½	C8	Physical Chemistry	2½
C9	Organic High Polymer Chemistry	2½	C10	Physical Chemistry of High Polymers	2½
E-102	Rubber Technology	2½	E-117	Rubber Technology	2½
		7½			7½

FIFTH YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
C11	High Polymer Lab.	2½	C12	High Polymer Lab.	2½
E-104	Rubber Technology	2½	E-119	Rubber Technology	2½
		5			5

ASSOCIATE DEGREE

COURSE DESCRIPTIONS

C-1 and C-2 General Chemistry. Two semesters of basic Inorganic Chemistry for those with no previous knowledge of Chemistry. The fundamental laws of Chemistry; the preparation, properties and uses of metals, non-metals and related compounds; and simple chemical calculations. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 10 credits.

C-3 Qualitative Analysis. The systematic analysis of inorganic compounds, carried out by the student in the laboratory using semi-micro technique. Chemical calculations and the balancing of chemical equations are covered in the stoichiometry portion of the course. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 5 credit hours.

C-4 Quantitative Analysis. One semester of quantitative analysis for those not desiring college credit in Chemistry but who wish to develop laboratory skills and techniques of a practical nature. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 5 credits.

C-5 and C-6 Organic Chemistry. A study of the important classes of carbon compounds and the fundamental theories of Organic Chemistry. Lecture, 7—9:30 P.M., Laboratory, 7—9:30 P.M. 10 credits.

C-7 and C-8 Physical Chemistry. This subject is designed for those in the laboratory or industry. It includes a discussion of properties of gases, liquids, solids, and solutions; chemical equilibrium, phase equilibrium, thermochemistry, electrochemistry, and other topics according to the need of the students. Laboratory work is assigned as required to give the student practice in the methods and apparatus of Physical Chemistry. Laboratory work includes the measurement of vapor pressure, viscosity, surface tension, heat of combustion and reaction, conductivity, determination of molecular weight, pH by various methods, etc. One Lecture 7—9:30 P.M. and one Laboratory 7—9:30 P.M. per week. 10 credits.

C-9 and C-10 High Polymer Chemistry. The chemical structure of high polymers and their manufacture and preparation. The chemical reactions of plastics and their physical properties in relation to their chemical structure. This subject is designed for those in the plastics industry who desire to keep abreast of modern theory or broaden their background. Lecture, 7—9:30 P.M. 5 credits.

C-11, C-12, C-13, C-14 See E-92, E-94, E-103, E-105.

C-15 and C-16 General Colloid Chemistry. The basic general principles of colloidal chemistry, followed by elementary analyses of important problems encountered in amorphous materials such as paints, cellulosic products, leather, paper, and textiles. Lecture, 7—9:30 P.M. 5 credits.

E-1 Alternating-Current Machinery Laboratory II. Tests on the single-phase and three-phase induction motors, the brush-shifting motor, investigation of induction motor windings, and tests on the Amplidyne generator. 2½ credits.

E-2 Advanced Electronics Laboratory II. Frequency and phase modulation and demodulation circuits. Video amplifiers, television pulse generators, multivibrators and counters. 2½ credits.

E-3 Advanced Electronics Laboratory I. Audio frequency amplifiers, intermediate frequency amplifiers, mixers, phase inserters, self-excited oscillators, frequency multipliers. Testing and alignment of complete receivers. Class C radio frequency amplifiers and amplitude modulation methods. 2½ credits.

E-5 Algebra. Fractions, linear and quadratic equations, functions and graphs, systems of equations, determinants, exponents, variation, binomial theorem, theory of equations, and complex numbers. 2½ credits.

E-6 Alternating-Current Machinery. Alternating current generation, alternator regulation, parallel operation, single-phase and three-phase transformers, vector diagrams, losses and efficiency, polyphase induction motors, torque and speed, power factor, methods of starting, synchronous motors, effect of field excitation and load, power factor correction, single-phase motors, methods of starting, testing of a.c. generators and motors. 2½ credits.

E-8 Alternating-Current Machinery Laboratory I. Measurements of current and voltage in single phase a.c. circuits containing resistance and reactance, power measurement in three-phase circuits, transformer efficiency and regulation, constant current transformer, efficiency and regulation of alternators, synchronous motors, single-phase motors, characteristics of three-phase induction motors, circle diagram, speed-torque curves, speed control by means of a Thyratron. 2½ credits.

E-10 Alternating Currents. Principles of alternating currents and voltages, impedance, reactance, vector representation, instantaneous and average power, series and parallel circuits, resonance, three-phase circuits, delta and wye-connections, three-phase power. 2½ credits.

E-11 and E-13 Analytic Geometry & Differential Calculus. Straight line, conic sections, differentiation of algebraic, trigonometric, logarithmic, and exponential functions, differentials, rates, slopes of curves, maxima and minima. 5 credit hours.

E-15 Applied Leather Analysis. A subject designed to acquaint the student with the accepted methods of analysis of the American Leather Chemists Association and other supplementary procedures. 2½ credits.

E-18 and E-19 Applied Mechanics. The fundamentals of statics, including such topics as force systems, laws of equilibrium, friction, centers of gravity, moments of inertia, stress fundamentals, strain, bending moment and deflection. 5 credits.

E-29 Direct-Current Machinery. Generator principles, armature and field windings, types of generators, armature reaction, compensation, characteristics of shunt and compound generators, amplidyne, motor principles, shunt motor, series motor, compound motor, motor controllers and starters, motor testing, applications of d.c. generators and motors. 2½ credits.

E-31 Direct-Current Machinery Laboratory. Direct-current generator connections, compound generators, parallel operation of generators, efficiency measurements, starting rheostats for d.c. motors, shunt motor characteristics, series motors, compound motors, efficiency of d.c. motors, determination of stray power losses, operation of balancer set, dynamotor. 2½ credits.

E-32 Electronics for Industry Laboratory. Characteristics of high-vacuum triodes, thyratron characteristics, grid-control methods, control by phase shifting, resistance-welding controls, synchronous timing, thyratron photoelectric relay, heating and lighting controls, speed and voltage regulators for d.c. motors and generators, polyphase rectifiers, saturable reactors, ignition rectifier. 2½ credits.

E-33 Direct Currents. Units of current, resistance and voltage, resistance of wires, temperature coefficient, series circuits, parallel circuits, Ohm's law and Kirchoff's law, energy and power, Thevenin's theorem, magnetic fields and lines of force, magnetic fields produced by electric currents, electromagnets, d.c. ammeters and voltmeters, the electric field, properties of dielectrics. 2½ credits.

E-34 Electronic Laboratory. Electron dynamics, thermionic emission, characteristics of vacuum and gas diodes, triodes. Equivalent circuits for tubes, voltage and power amplifiers. Photo-cells, cathode ray oscilloscopes, impedance bridge and vacuum tube voltmeters (must be taken concurrently with E-36). 2½ credits.

E-36 Electron Tubes and Circuits II. Vacuum tube amplifiers of all classes; distortion; coupling methods; inverse feedback in amplifiers. 5 credits.

E-37 Electronics for Industry. Single and polyphase rectification and filtering. Basic electron tubes; voltage and current stabilization circuits; thyratron and photo-tube control circuits and applications. 2½ credits.

E-38 and E-45 Engineering Drawing. Freehand and mechanical drawing, including lettering, geometric construction, orthographic projection, isometric and cabinet drawing, and dimensions, auxiliary views, cross sections, advanced dimensioning, sketching of machine parts, working drawings, tracing and blueprinting, intersections, and developments. 5 credits.

E-39 Electronic Physics. Introductory field theory applied to propagation in free space, dielectrics, and conductors. Reflection and refraction of waves; interference, diffraction, and polarization. Transmission lines; antennas; impedance matching. Properties of the ionosphere. 2½ credits.

E-40 Frequency Modulation and Television. Principles of conveying electronic visual information by wire, radio photo, facsimile, and television. Television systems: generation transmission and reception of television signals. 5 credits.

E-41 Electron Tubes and Circuits I. Electron dynamics, thermionic emission, secondary emission, field emission, and photo-electric emission. Mechanical design consideration of radio tubes. Tube characteristics and coefficients. The application of radio tubes to amplifier circuits and rectifiers. 5 credits.

E-43 Electrical Measurements. Measurements of resistance, capacitance, inductance, impedance, voltage, current, and power. DC and AC bridge circuits, magnetic measurements, frequency and phase measurements. 2½ credits.

E-46 and E-53 Heat Engineering. The basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A brief treatment of steam engines, turbines and pumps. Special consideration is given to the use of steam in manufacturing processes. 5 credits.

E-48 Hydraulics. Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs; orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids, Mach's number; dynamical similitude and Pi theorem. 2½ credits.

E-52 Integral Calculus. Indefinite & definite integrals, areas, length of curves, area of surface of revolution, volumes of solids of revolution, integration of trigonometric, logarithmic, and exponential functions, methods of integration. 2½ credits.

E-54 Leather Histology. A study of the structures of animal skin and of the changes which they undergo in the leather-making process. Because the basically extracellular nature of skin demands it, considerable time is devoted to the nature and function of the fundamental protein constituents. 2½ credits.

E-55 Job Evaluation and Merit Rating. Covers the principles and practices in the analysis of: 1, the job and 2, the workers' performance on that job. Specific

subjects covered include job description, determining job factors and translating these into rating values, wage calculations and wage structures.

E-56, E-57, E-58, E-59 Leather Technology. Introduction to the technology of leather manufacture. The first two semesters are devoted to examining government regulations in imported hides and skins, studying the purchasing of hides and skins, and classifying various hide damages. This is followed by work on the handling of raw stock at the tannery, unhairing, bating, and hide classification. The third and fourth semesters are concerned primarily with the study of vegetable tanning, chrome tanning, and various other types of tanning. In the work throughout the year the material covered in lectures is supplemented by laboratory studies on a small scale. 10 credits.

E-66 and E-67 Machine Design. The design of machine elements, such as fasteners, shafts, frames, bearings, gears, clutches, springs, keys and drives. Data for most of the problems are taken from actual machines in the various laboratories. 5 credits.

E-68 and E-69 Machine Drawing. Several short problems involving centers of gravity, counterweights, cam layouts, piping, welding, sheet metal drafting, and assembly drawings. 5 credits.

E-78 and E-79 Mechanical Engineering Laboratory. Fundamentals of engineering measurements, flow measurement of steam and air, tests of steam turbine and internal combustion engine, experimental work with refrigeration units, measurements of heat transfer, combustion, fluid flow, performance of pumps, and testing of engineering material. 5 credits.

E-80, E-82, E-91, E-93 Paper Manufacturing — Testing and Analysis. An elementary study of the fundamental processing techniques used in paper manufacture. The lecture work is accompanied by laboratory training in paper making, paper testing and analysis, and paper microscopy. 10 credits.

E-81 Mechanism. The basic principles of kinematics, in which the wide variety of process machinery available furnishes many specific examples. Frequent use of these mechanisms is made in the development of the subject. Some of the important topics covered are the following: rolling cylinders and cones, gearing, gear train design, epicyclic gear trains, flexible connectors including stepped pulley and cone design, cam design, linkages, and miscellaneous mechanisms. 2½ credits.

E-84, E-86, E-87, E-89 Paper Technology. Lectures on the production and technology of pulp and paper.

E-90 and E-99 Physics. The fundamentals of mechanics, heat, sound, electricity, and light. The first semester topics include force systems, energy and power, motion, liquids and gases, calorimetry and thermodynamics. The second semester topics include wave motion, sound phenomena, magnetism, electrostatics, D.C. and A.C. circuits, reflection and refraction of light, lenses, optical instruments, physical optics and elements of atomic physics. 5 credit hours.

E-92 and E-103 Plastic Technology. This is an introductory study of plastics. It includes history, classification, properties, definitions and uses. Raw materials, methods of manufacturing, processing and fabrication. Lectures and laboratory. 5 credits.

E-94 and E-105 Plastic Technology. Additional instruction in processing and fabrication. Applications of plastics, engineering properties, equipment, mold and product design. Testing of plastics. Lectures and laboratory. 5 credits.

E-95 Physical Testing of Leather. A practical and theoretical study of the characteristics of leather in relation to the end use. Studies are made on meas-

uring and classifying the effect of changes in manufacturing procedure, both chemical and physical. Leather, because it is a natural product, varies considerably within the same hide. Thus, the nature of this variation is very important and the study of any changes affecting it is, in turn, important. 2½ credits.

E-96 Principles of Production Planning. The student is introduced to the processes followed in planning from the original idea of the product to the shipment of the finished product from the plant. Among the topics covered are product analysis, plant location and layout, organization, budgeting and control. 2½ credits.

E-100 Research Problems in Leather. This subject is designed primarily to enable the student to put into practical application the various scientific principles of physics, chemistry, mathematics, economics, etc. on problems of an industrial nature. This may encompass anything from the design and layout of any of a number of special leather plants to the suggested solution of practical problems which arise in the operation of a modern business. 2½ credits.

E-102 and E-117 Fundamentals of Rubber Technology. An introductory course for those who wish to acquire a general knowledge of rubber technology. Physical properties, composition, compounding, vulcanization, evaluation, deterioration, etc., of various types of synthetic rubbers and natural rubber. Lectures and laboratory. 5 credits.

E-104 and E-119 Advanced Rubber Chemistry and Technology. Monomers, polymerization systems, relation of chemical structure to physical properties, theories of vulcanization, acceleration, reinforcement, and deterioration of elastomers. Lectures and demonstrations. 5 credits.

E-106 Semi-Conductors and Transistors. An introduction to solid state electronics. Crystal diodes transistors; their operation and applications. 2½ credits.

E-108 and E-123 Strength of Materials. This subject covers such topics as beams, beam design, torsion, columns, combined stresses, reversals of stress and impact. Includes such topics as bending and shearing stresses, torsion, compound beams and columns, reversals of stress, impact, vibrations, stress analysis by strain gage methods, concepts of creep and relaxation. 5 credits.

E-112 Transmission and Distribution of Power. Transmission systems, reactance, capacitance, three-phase line calculations, corona power, lightning arresters, transmission structures, transformer substations, distribution circuits, automatic substations. 2½ credits.

E-114 Trigonometry. Trigonometric functions, identities, reference angles, radians, multiple angles, trigonometric equations, logarithms, slide rule, right triangles, and oblique triangles. 2½ credits.

E-115 - Communication Engineering. Theory and applications of thermionic tubes and transistors in amplifiers, oscillators, modulators, and detectors. Selectivity, sensitivity, stability of radio receivers and transmitters. 5 credits.

E-118 Work Simplification. The study of cost reduction through the analysis of the job, plant layout, tools and equipment, and worker activity through the use of process, flow, operation and man and machine charts and the principles and practices of motion study. 2½ credits.

E-127 Time Study. The methods and rules of time study. A brief historical background is given before the student is introduced to the techniques of making time studies. Specific points covered include job standards, use of allowances, treatment of variables, use of data, "normal performance" and rating procedures. 2½ credits.

CERTIFICATE COURSES

GENERAL INFORMATION

Entrance Requirements

For subjects taken toward a certificate, the requirement, in general, is graduation from grammar school or equivalent education.

Tuition for subjects not offering college credit is free to Lowell Technological Institute day students and residents of Lowell, but non-residents will be charged as follows:

Evenings Per Week	*Hours Per Evening*	*Tuition*
1	2	$ 5.00
1	2½	6.25
1	3	7.50
2	2	10.00
2	2½	12.50
2	3	15.00
3	2	15.00
3	2½	18.75
3	3	22.50

All tuition and fees must be paid in full at the time of registration.

To receive free tuition, residents of Lowell must file a certificate of residence with the Registrar. These certificates may be obtained from the Election Commission, City Hall, Lowell. However, registration may be completed prior to filing the certificate.

Size of Class

No first-year subject will be given unless at least 15 students register for it. In a few instances, more than that number are required. Advanced subjects will usually, but not necessarily, be given, regardless of number.

Attendance

Students must attend 70% of classes held in order to receive a certificate for the subject. Four unexplained absences in a row will result in the student's being automatically dropped from the rolls.

College Credit

A few of the certificate courses are given on the college level and carry college credit. They are so indicated on the course listings and subject descriptions. For these courses the tuition fees for college credit courses, as shown on page 9 apply.

CHEMISTRY

First Semester Subjects (Sept. - Jan.)

7 - 9:00 p.m.

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
CH-101	College Chemistry (4 credits)	Mon., Tues. & Thurs.	C-2
C-23	Textile Chemistry & Dyeing	Mon., Tues. & Thurs.	C-39
C-25	Textile Chemistry & Dyeing	Mon., Tues. & Thurs.	C-24
C-27	Modern Chemistry for the Engineer and Scientist	Thursday	B.S. Degree

ENGINEERING

E-7	Algebra	Mon. & Wed.	None
E-9	Algebra	Mon. & Wed.	E-7
E-17	Applied Mathematics	Mon. & Wed.	None
E-17A	Applied Mathematics	Mon. & Wed.	E-17
E-21	Architectural Drawing	Tues. & Thurs.	E-73
E-23	Architectural Drawing	Tues. & Thurs.	E-21
E-25	Blueprint Reading	Mon. & Wed.	None
E-27	Analytical Geometry and Calculus (4 credits)	Tues. & Thurs.	E-114
E-35	Electronics (3 credits)	Mon. & Wed.	College Math. & Physics
E-47	Fundamentals of Electronics	Tues. & Thurs.	E-10
E-49	Fundamentals of Plastics	Monday	None
E-51	Geometry of Engineering Drawing	Tues. & Thurs.	E-77, E-23
E-61	Leather Technology	Tues. & Thurs.	None
E-63	Machine Shop Practice	Mon. or Wed.	None
E-65	Machine Shop Practice	Tues. & Thurs.	E-63
E-71	Mechanical Drawing	Mon. & Wed.	None
E-73	Mechanical Drawing	Tues. & Thurs.	E-71
E-75	Mechanical Drawing	Tues. & Thurs.	E-73
E-77	Mechanical Drawing	Tues. &Thurs.	E-75
E-85	Oil Heating	Mon. & Wed.	None
E-97	Physics	Tues. & Thurs.	E-17
E-107	Pulp and Paper Technology	Tuesday	None
E-109	Pulp and Paper Testing Lab.	Wednesday	E-107 Concurrently
E-111	Statistical Quality Control	Mon. & Thurs.	None
E-121	Rubber Technology	Monday	None
E-125	Textile Testing	Tues. & Thurs.	None
E-129	Trigonometry	Tues. & Thurs.	E-16
MA-206	Differential Equations (3 credits)	Tues. & Thurs.	MA-202
MA-301	Advanced Calculus (3 credits)	Tues. & Thurs.	MA-202

CHEMISTRY

SECOND SEMESTER SUBJECTS (JAN. - MAY)

7 - 9:00 P.M.

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
CH-102	College Chemistry (4 credits)	Mon., Tues. & Thurs.	CH-101
C-24	Textile Chemistry & Dyeing	Mon., Tues. & Thurs.	C-23
C-26	Textile Chemistry & Dyeing	Mon., Tues. & Thurs.	C-25

ENGINEERING

E-4	Advanced Paper Technology	Tuesday	E-107
E-12	Air Conditioning — Heating & Ventilation	Mon. & Wed.	E17, E-88
E-14	Algebra	Mon. & Wed.	None
E-16	Algebra	Mon. & Thurs.	E-14
E-17	Applied Mathematics	Tues. & Thurs.	None
E-17A	Applied Mathematics	Mon. & Wed.	E-17
E-21	Architectural Drawing	Tues. & Thurs.	E-73
E-23	Architectural Drawing	Tues. & Thurs.	E-21
E-24	Blueprint Reading	Mon. & Wed.	None
E-26	Analytical Geometry and Calculus (4 credits)	Tues. & Thurs.	E-27
E-28	Chemistry of Plastics (2 credits)	To Be Arranged	College Chem. thru Org.
E-30	Diesel Engines	Mon. & Wed.	None
E-42	Fundamentals of Electronics	Mon. & Wed.	E-10
E-44	Geometry of Engineering Drawing	Tues. & Thurs.	E-51
E-50	Industrial Electronics	Tues. & Thurs.	E-47
E-60	Leather Technology	Tues. & Thurs.	E-61
E-63	Machine Shop Practice	Mon. or Wed.	None
E-65	Machine Shop Practice	Tues. & Wed.	E-63
E-71	Mechanical Drawing	Mon. & Wed.	None
E-73	Mechanical Drawing	Tues. & Thurs.	E-71
E-75	Mechanical Drawing	Tues. & Thurs.	E-73
E-77	Mechanical Drawing	Tues. & Thurs.	E-75
E-88	Physics	Tues. & Thurs.	E-17
E-98	Principles of Radio	Mon. & Wed.	E-47
E-111A	Advanced Quality Control	Thursday	E-111
E-116	Trigonometry	Tues. & Thurs.	E-14
MA-206	Differential Equations (3 credits)	Tues. & Thurs.	MA-202
MA-302	Advanced Calculus (3 credits)	Tues. & Thurs.	MA-202

GENERAL STUDIES

First Semester Subjects (Sept. - Jan.)

7 - 9:00 p.m.

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
G-1	Accounting I	Mon. & Wed.	None
G-9	American Poetry (2 credits)	Mon. & Thurs.	1 Year College English
G-3	Appreciation of World Literature	Tues. & Thurs.	None
G-7	Business Law	Tues. & Thurs.	None
G-11	Cost Accounting	Monday	G-2
G-13	Costume Design	Tues. & Thurs.	None
G-15	English Composition	Tues. & Thurs.	None
G-45	Essay (2 credits)	Mon. & Thurs.	1 Year College English
G-17	Fashion Illustration	Tues. & Thurs.	G-21
G-21	Freehand Drawing	Mon. & Wed.	None
G-21	Freehand Drawing	Tues. & Thurs.	None
G-23	Fundamentals of Public Relations	Monday	None
G-49	Government Contracts	Tues. & Thurs.	None
G-25	Great English and American Writers (3 credits)	Monday	1 Year College English
G-27	Industrial Psychology	Wed. & Fri.	None
G-29	Industrial Relations	Tues. & Thurs.	None
G-33	Principles of Advertising	Tues. & Thurs.	None
G-35	Principles of Retailing	Tues. & Wed.	None
G-37	Principles of Salesmanship	Tues. & Wed.	None
G-43	Silk Screen Printing	Tues. & Thurs.	None
G-47	Vocabulary Building	Mon. & Wed.	None

GENERAL STUDIES

Second Semester Subjects (Jan. - May)

7 - 9:00 p.m.

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
G-2	Accounting II	Mon. & Wed.	G-1
G-9A	American Poetry (2 credits)	Mon. & Thurs.	1 Year College English
G-4	Appreciation of World Literature	Tues. & Thurs.	None
G-8	Comparative Literature (3 credits)	Monday	1 Year College English
G-10	Costume Design	Mon. & Wed.	G-13
G-16	English Composition	Tues. & Thurs.	G-15
G-45A	Essay (2 credits)	Mon. & Thurs.	1 Year College English
G-49A	Government Contracts	Tues. & Thurs.	None
G-24	Life Drawing	Tues. & Thurs.	G-21
G-26	Meaning and Use of Words	Mon. & Wed.	None
G-30	Pastel Drawing	Tues. & Thurs.	G-21
G-35	Principles of Retailing	Tues. & Wed.	None
G-37	Principles of Salesmanship	Tues. & Wed.	None
G-38	Techniques of Leadership	Tues. & Thurs.	None
G-40	Water Color	Tues. & Thurs.	None

TEXTILE MANUFACTURING

First Semester Subjects (Sept. - Jan.)

7 - 9:00 p.m.

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
M-28	Cotton Design	Tues. & Thurs.	M-27
M-11	Cotton Yarns	Tues. & Thurs.	None
M-13	Cotton Yarns	Mon. & Wed.	M-12
M-51	Elementary Textile Design	Mon. & Wed.	None
M-15	Knitting	Tues. & Thurs.	None
M-24	Loom Fixing	Tues. & Thurs.	M-33
M-33	Power Weaving	Mon. & Wed.	None
M-32	Power Weaving and Warp Preparation	Tues. & Thurs.	None
M-3B	Reprocessed and Reused Fiber Manufacture	Monday	M-1 (or equivalent) & M-2
M-3C	Synthetic Yarn Manufacture on Woolen System	Tuesday	M-3A
M-2	Technology of Natural and Man-made Fibers	Mon. & Tues.	None
M-1	Textile Mechanism and Calculations	Thursday	None
M-8	Top Mill Organization	Thursday	M-4
M-30	Woolen & Worsted Design	Tues. & Thurs.	M-29
M-10	Woolen & Worsted Finishing	Mon. & Wed.	None
M-5	Worsted & Synthetic Yarn Manufacturing	Wed. & Thurs.	M-4

Second Semester Subjects (Jan. - May)

NUMBER	SUBJECT	EVENINGS	PRE-REQUISITE
M-27	Cotton & Synthetic Design	Mon. & Wed.	M-51
M-18	Cotton & Synthetic Finishing	Mon. & Wed.	C-38 & M-51
M-12	Cotton Yarns	Tues. & Thurs.	M-11
M-14	Synthetic Yarn Manufacture on the Cotton System	Mon. & Wed.	M-13
M-7	Tow to Top—Synthetic and Man-made Fiber	Thursday	M-4
M-6A	Wool & Staple Synthetic French Combing	Thursday	M-4
M-4	Wool & Staple Synthetic Top Manufacture	Mon. & Tues.	M-1 (or equivalent) & M-2
M-6B	Wool & Staple Synthetic Yarn Manufacture on the French System	Wednesday	M-4
M-29	Woolen Design	Mon. & Wed.	M-51
M-3A	Yarn Manufacturing by Woolen System	Mon. & Tues.	M-1 (or equivalent) & M-2

CERTIFICATE
COURSE DESCRIPTIONS

C-23, C-24, C-25, C-26 Textile Chemistry and Dyeing. The action of chemical reagents on the natural and synthetic fibers; the preparation of fibers for dyeing; the application of all classes of dyes to cotton, wool, silk, synthetic and union materials; and the testing techniques involved in measuring fastness to light, washing, crocking, perspiration, etc. One lecture, 7—9 P.M., and two laboratories, 7—9 P.M., per week.

C-27 Modern Chemistry for the Engineer and Scientist. A course for the graduate in physical science and engineering perhaps a decade or more beyond his college graduation for the purpose of bringing him up to date in a series of special chosen fields in chemistry. Text: Modern Chemistry for the Engineer and Scientist. Edited by G. Ross Robertson.

CH-101 and CH-102 College Chemistry. Two semesters of Inorganic Chemistry, open to those who have passed C-32 or a satisfactory course in high school Chemistry. Two lectures, 7—9 P.M., and one laboratory, 6:30—9:30 P.M., per week. College level; 4 credit hours per semester.

E-4 Advanced Paper Technology. Details of manufacture of various papers and their conversion to a useful end product. Guest lecturers supplement the regular staff.

E-7 and E-14 Algebra. Algebra, including addition, multiplication, subtraction, division, factoring and fractions.

E-9 and E-16 Algebra. A continuation of E-7 and E-14. Some of the topics treated are: graphical representation, linear equations, radicals, quadratic equations, logarithms, slide rule, and some trigonometry.

E-12 Air Conditioning — Heating and Ventilation. The principles of air conditioning covering the fundamental laws, physical properties of the atmosphere, measuring instruments, heating, cooling, humidification and dehumidification systems, air filtration, refrigeration, etc. Lectures and assignments.

E-17 and E-17A Applied Mathematics. Designed for students who need a review of the fundamental process of and includes some plane and solid geometry, algebra, logarithms, and trigonometry. Use of the slide rule is stressed in the solution of practical problems.

E-21 and E-23 Architectural Drawing. The first semester covers problems of detailing and alteration such as a young draftsman might encounter in an architect's office. The second semester takes up design of a small house including floor plan, elevations, section, details, heating, plumbing and electrical drawings, as well as cost estimates.

E-24 Blueprint Reading. Similar to E-25, but with emphasis on architectural, rather than engineering, blueprints.

E-25 Blueprint Reading. The principles of mechanical drawing, *e.g.*, projections, sections, dimensioning, etc., necessary for the understanding of blueprints.

E-26 and E-27 Calculus and Analytic Geometry. The first semester covers differential calculus with the necessary analytic geometry; the second semester covers integral calculus. 8 credits.

E-28 Chemistry of Plastics. The chemical structure of high polymers and their manufacture and preparation. The chemical reactions of plastics and their

physical properties in relation to their chemical structure. This subject is designed for those in the plastics industry who desire to keep abreast of modern theory or broaden their background. College level; 2 credit hours.

E-30 Diesel Engines. An elementary study of Diesel engines, their operation, and maintenance. Types of Diesels, fuel oils, fuel injection systems, combustion, cooling systems, application, maintenance, etc. Lectures and assignments.

E-35 Electronics. A more advanced treatment of the fundamentals of electronics than E-40, offered for those who have completed college mathematics and physics. Topics included are: alternating current circuits, fundamental properties of thermionic and photoelectric tubes, amplifiers, rectifiers, oscillators, coupled circuits, and filters. College level; 3 credit hours.

E-42 and E-47 The Fundamentals of Electronics. Topics include: vacuum tube theory, vacuum tube applications including rectifiers, power supplies, amplifiers, classes of amplifiers, voltage gain and power amplifiers, electronic instruments, etc. Lectures and laboratory.

E-44 and E-51 Geometry of Engineering Drawing. The theory of orthographic drawing and the study of space relationships of lines, planes, and solids.

E-49 Fundamentals of Plastics. An introductory study for those who wish to acquire a general knowledge of plastics. Classification, description, chemical and physical properties, uses, and methods of fabrication.

E-50 Industrial Electronics. The theory and operating characteristics of gas and vacuum tubes, photo-electric cells, and the thyratron. Topics covered include: amplifiers, electronic relays and timers, thyratron applications, phase shifts, inverters, rectifiers, motor and welder control, textile and other applications. Lectures and laboratory.

E-60 and E-61 Leather Technology. The theoretical aspects of leather production coupled with a laboratory to carry out the planning of process control, material control, and product quality control. One section will be devoted to an intensive introduction to the histology of hides and skins and histological preparations.

E-63 and E-65 Machine Shop Practice. Metal working, including bench work, lathes, grinders, planers, shapers, presses, milling machines, care of tools, tool grinding, heat treatment, forging, use of special tools, etc. The classes are limited to 25 students.

E-71, E-73, E-75, E-77 Mechanical Drawing. Fundamentals of engineering drawing. The first semester covers lettering, use of instruments, geometric construction, orthographic projection, multi-view and pictorial freehand drawing. The second semester includes dimensioning, auxiliary views, cross sectioning, screw threads and working drawings. The third semester offers intersections, pictorial drawings and applications to sheet metal drawings. The fourth semester covers assembly drawings from details of parts and detailing from designers' assembly drawings.

E-85 Oil Heating. Fundamentals of heating systems, oil burners, controls, installation, and service.

E-88 and E-97 Physics. Elementary physics on the high-school level. Lectures and demonstrations.

E-98 Principles of Radio. Audio systems, microphones, loud-speakers, radio wave propagation, antennas, transmission lines, amplitude and frequency modulation, radio transmitters, modulators, detectors, receivers, tracking and alignment, servicing instruments, etc. Lectures and laboratory.

E-107 Pulp and Paper Technology. The basic principles of manufacture of the common papermaking pulps, followed by a study of stock preparation and paper machine operation.

E-109 Pulp and Paper Testing Laboratory. Laboratory work in the physical and chemical testing of pulps and papers.

E-111 Statistical Quality Control. This course starts off with instruction in the basic statistical concepts needed to understand and use the tools of Quality Control. It then proceeds to introduce and illustrate some of these "statistical tools." Subjects covered are: measures of central tendency and dispersion, normal curve analysis, simple process capability studies, basic control charts for measurable and non-measurable characteristics, acceptance sampling techniques and determination of tolerances. The emphasis is placed on the practical rather than the mathematical approach to quality problems. Case studies, audio-visual aids and practical demonstrations are used to supplement the lectures.

E-111A Advanced Quality Control. This course will deal with some of the more advanced methods developed to aid in the solution of quality problems in industry. Techniques of process analysis and process control such as the Span Plan, modified control limits, Narrow Limit Gaging, and Pre-Control will be introduced and illustrated. Tests of significance such as: the X^2 test, the "t" test, the "F" test, and some non-parametric tests will be discussed. The course will also spend some time acquainting the student with some of the practical aspects of organization, administration, and economics of a Quality Control program.

E-116 and E-129 Trigonometry. The solution of all triangles by both natural and logarithmic functions, identities, radian measure, principal values and the solution of trigonometric equations.

E-121 Rubber Technology. An introductory course for those who wish to acquire a general knowledge of rubber technology.

E-125 Textile Testing. A study of the methods used in the determination of the physical properties of textiles and the interpretation of test data. Topics include: a consideration of textile fibers and their properties, testing machines, breaking strength, elongation, fabric structure, tearing strength, thickness, bursting.

MA-206 Differential Equations. A review of series and partial differentiation, first- and second-order differential equations, and first- and second-order partial differential equations. Practical applications for the chemist and the engineer. 3 credits.

MA-301-302 Advanced Calculus. Ordinary differential equations, Laplace transformation, numerical methods of solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations, partial differential equations of mathematical physics, and complex variable theory. 6 credits.

G-1 and G-2 Accounting I and Accounting II. The principles of accounting. The first semester deals with the preparation and interpretation of reports and statements of financial position. The balance sheet, profit and loss statement, theory of debits and credits, ledger, etc., are covered. The second semester carries the student into payroll and tax accounting, partnership and corporate records and the basic principles of cost accounting.

G-3 and G-4 Appreciation of World Literature. Designed to increase the student's enjoyment of great literature of all types. The first semester covers American literature and its historical background; the second semester takes up British and Continental masterpieces.

G-7 Business Law. The basic legal principles of use to people in the conduct of their everyday affairs. Topics covered include contracts, mortgages, deeds, negotiable instruments, easements, conditional sales, partnerships and corporations.

G-8 Comparative Literature. This course aims to develop standards of literary criticism and to familiarize the student with six or more classics of western civilization. Lectures, class discussion, and critical papers form the basis of class meetings. College level; 3 credit hours.

G-9 and G-9A American Poetry. First semester: a survey of American poetry of the nineteenth century with concentrated study of six of the foremost poets of the period. College level; 2 credit hours. Second semester: the triumph of realism in American poetry of the twentieth century. This course will acquaint students with well-known works of Robert Frost, Carl Sandburg and others of the period. College level; 2 credit hours.

G-10 and G-13 Costume Design. The first semester studies methods of altering a commercial garment pattern to suit the requirements of any figure. The second semester deals with the drafting of original patterns.

G-11 Cost Accounting. An introduction to the study of the process of recording the expenses of operating a business from the standpoint of determining production and distribution costs.

G-15 English Composition. The basic elements of composition, including remedial English, grammar, sentence structure, etc.

G-16 English Composition. Writing for business and social purposes. Narration, description, reports, letters, etc.

G-17 Fashion Illustration. Training in fashion illustration as applied to promotion and advertising display.

G-21 Freehand Drawing. Drawing in charcoal from casts and group arrangements of still life.

G-23 Fundamentals of Public Relations. Basic techniques of press, radio, and television publicity with fundamental training in communications procedures, the social implications and professional responsibility of all media. Evaluation of promotional programs devised to create and ensure public awareness and goodwill.

G-24 Life Drawing. Drawing from the live model in charcoal or in pastel. Individual and class instruction in anatomy.

G-25 Great English and American Writers. Attention is focused on six or seven major writers. Emphasis will be on discovering what these authors have to say that is of interest or importance to the general reader today. The student will have the opportunity to determine the attitude toward life of each writer, to see what gave rise to this attitude, and to evaluate it and compare it with the views of other writers considered in the course. College level; 3 credit hours.

G-26 The Meaning and Use of Words. The exact meaning of words and how their proper usage can lead to clear and dynamic speech.

G-27 Industrial Psychology. A human relations approach to the study of the operation of basic psychological principles in industrial situations. The subject is designed for foremen and other supervisory personnel, not professional psychologists. Emphasis is placed on the relationships between worker efficiency and behavior, attitudes, fatigue, frustration, morale, motivation, etc. Some attention is given to causes of accidents and accident prevention, and to the problem of labor turnover. Selected case studies supplement text readings.

G-29 Industrial Relations. The underlying principles of harmonious relations between employer and employee. Some of the topics covered are: company policies and the foreman, employee morale, grievances, wages, training, collective bargaining, unions, government regulations, arbitration, etc.

G-30 Pastel Drawing. Drawing in pastel from still life group arrangements.

G-33 Principles of Advertising. The fundamentals of advertising: psychology, copy writing, layout, production, testing, campaigns, etc. Lectures and assignments.

G-35 Principles of Retailing. Stores—types, location, and organization. Merchandise—purchasing, preparing for resale, promoting, selling, advertising and displaying. Record keeping, planning, and merchandising calculations.

G-37 Principles of Salesmanship. The fundamentals of salesmanship: the psychology of selling, building a selling talk, showmanship, elements of successful selling, wholesale and retail salesmanship, etc. Lectures plus student participation.

G-38 Techniques of Leadership. Designed to aid the industrial supervisor to relate his own behavior to that of the group under his supervision. The dynamics of leadership and of the group receive primary emphasis. The concepts, values, and limitations of democratic and authoritarian leadership are treated through case studies and textual readings. Leadership as expressed through inter-personal relationships, and the resolution of social conflict both by integration and the democratic process provide the practical basis for this subject.

G-40 Water Color. This course is designed to acquaint students with various styles and techniques of this popular medium and also to enhance their understanding of shape, form, line and texture and the rules of color harmony and contrast. Students will work from still-life groups and individual instruction will be given.

G-43 Silk Screen Printing. Stencilling and printing on textiles and paper with the silk screen.

G-45 and G-45A Essay. First semester: study and appreciation of the essay as a type of literature with selected readings of well-known essayists of the nineteenth century. Second semester: will feature American essayists and their contribution to literature. College level; 2 credit hours.

G-47 Vocabulary Building. A subject to help the student enlarge his vocabulary and improve his understanding and choice of words. Language roots and word evolution are also studied.

M-1 Textile Mechanism and Calculations. The mechanisms and mathematics required for an understanding of textile machines. Pulleys, cones, gears, levers, cranks, revolutions, surface speed, constants, ratio, proportion, formulae, slide rule, etc.- Lectures and demonstrations.

M-2 Technology of Natural and Man-made Fibers. Types of sheep and wool. Wool buying, selling, grading, sorting, scouring. Other animal fibers such as mohair, alpaca, camel, vicuna, etc. Man-made fibers, such as rayon, nylon, orlon, etc. Identification, tests, uses, properties. Theory and basic principles of yarn making by all systems. Explanation of mule spinning, frame spinning, roller drawing, porcupine drawing, pressed felt manufacture, etc. Lectures and demonstrations.

M-3A Yarn Manufacturing by Woolen System. The conventional woolen yarn system of picking and blending, carding and spinning, on both the mule and frame. Machine descriptions, adjustments, settings, maintenance, and processing techniques. Lectures and demonstrations.

M-3B Reprocessed and Reused Fiber Manufacture. The sources of reclaimed fiber, the sorting of raw materials and the carbonizing of rags. Rag picking, lumping, shredding, and garnetting. The Wool Products Labeling Act. Lectures and demonstrations.

M-3C Synthetic Yarn Manufacture on the Woolen System. Problems of processing synthetic fibers into yarn on woolen system machinery. The basic properties of synthetic fibers, techniques of processing, machine set-up, and special adjustments. Lectures and demonstrations.

M-4 Wool and Staple Synthetic Top Manufacture. The manufacture of wool or man-made fibers, such as cut staple rayon or synthetics, into top using some or all of the following operations: worsted type carding, backwashing, open and intersecting gilling, Noble Combing, Warner Swasey Pin Drafters, Holdsworth Gill Reducers. Mostly lectures, but sample lots of wool or synthetic fiber or blends are usually run in the laboratory as time permits.

M-5 Worsted and Synthetic Yarn Manufacture. Yarn making of wool or synthetic fiber or blends on the modified Bradford or English type of machinery. Roller drawing machines, worsted spinning frames, twisters and winders are studied as well as the newer short cut systems using the Warner Swasey Pin Drafter, Holdsworth Gill Reducer, etc. Other spinning systems, such as the Bird System, American System, Ambler, Saco-Lowell Draftall, Whitin Super-Draft are studied. Lectures and demonstrations, and sample lots of synthetics and wool or blends of all types of fibers are made into yarn in the laboratory when time permits. Spinning covers all phases of flyer, cap, ring, direct and centrifugal systems. Production, scheduling and routing problems are discussed with actual mill procedures as subject matter.

M-6A Wool and Staple Synthetic French Combing. The combing of shorter wools or synthetics on the so-called French Comb. Advanced intersecting gilling and blending of wool with other fibers and blends of synthetics. Mostly lectures, but modern equipment is available in the laboratory and usually small lots of wool or synthetics or blends are run.

M-6B Wool and Staple Synthetic Yarn Manufacture on the French System. The manufacture of wool or synthetics or blends into a French worsted type yarn. Intersecting gilling, open gilling with rub aprons, French or porcupine drawing. Short cut French systems using Pin Drafters and super draft porcupines, French Frame spinning, ring and mule twisting, winding. Mostly lectures, but modern laboratory equipment is available for demonstrations and running sample lots.

M-7 Tow to Top — Synthetic and Man-made Fiber. This subject covers in detail the processes and operations necessary to make top or sliver from synthetic or man-made tow. A detailed study is made of the Pacific Converter, Perlok system, Saco-Lowell Direct Spinner, etc. Mostly lectures, but sample lots are run on a Converter as time permits.

M-8 Top Mill Organization. Methods of calculating unit costs, personnel, work loads, cost of top, machinery layouts, supervisory help, production engineering. The over-all picture of an integrated woolen and worsted mill is considered to show how the top mill fits into the complete picture. The top mill is considered in detail. Lectures only.

M-10 Woolen and Worsted Finishing. The finishing of both woolen and worsted cloths. Some of the topics covered are: burling, mending, fulling, washing, speck dyeing, carbonizing, gigging, napping, steaming, brushing, shearing, and pressing. Lectures and some demonstrations.

M-11 Cotton Yarns. First semester of cotton yarn manufacture. Properties and characteristics of raw cotton; cultivating, ginning and marketing of raw cotton; mixing, opening and picking, and carding.

M-12 Cotton Yarns. Second semester of cotton yarn manufacture. Combing, lrawing, regular and long draft roving.

M-13 Cotton Yarns. Third semester of cotton yarn manufacture. Spinning, pooling, winding, and twisting.

M-14 Synthetic Yarn Manufacture on the Cotton System. The processing of taple synthetic fibers on the cotton system and the modifications of cotton type quipment to handle these fibers. The lectures are supplemented with labora-ory work.

M-15 Knitting. Yarns, yarn sizing, and the manufacture of knitted fabrics and arments from all types of yarn.

M-18 Cotton and Synthetic Finishing. The methods of converting both cotton nd synthetic fabrics from the gray to the finished state. All the major processes f both wet and dry finishing of these fabrics are discussed, including crease esisting, stabilizing, water repelling, flame repelling, heat setting, etc.

M-24 Loom Fixing. The timing of all different motions in the loom and emedies for improper settings. Box and harness chain planning and building. ectures and laboratory.

M-27 Cotton and Synthetic Design. Cloth analysis and design beginning with plain fabrics and leading into stripes and plaids, plus the construction, yarn lenier and filament count of various synthetic cloths.

M-28 Cotton Design. The design and analysis of more elaborate cotton fabrics, uch as extra warp and extra filling figured cloths, corduroys, velvets, ply fabrics, eno fabrics, etc.

M-29 Woolen Design. Cloth analysis and design, covering blanket, bathrobing, illing reversibles, extra warp and filling backs, figured effects, double cloths, plaid backs, triple cloths and four-ply fabrics.

M-30 Woolen and Worsted Design. This subject includes the more compli-ated fabrics, such as chinchilla, melton, and kersey, as well as suitings. Manu-acturing costs of woolen and worsted fabrics are also covered.

M-32 Power Weaving and Warp Preparation. Warp preparation in all systems s well as the Draper and Stafford automatic looms. Lectures and laboratory.

M-33 Power Weaving. The more complicated looms are studied, including lobby and Crompton & Knowles looms, as well as the Warner Swasey weaving machine. Weaving is primarily on woolen and worsted fabrics. Lectures and aboratory.

M-51 Elementary Textile Design. Weaves of all types, from the plain weave hrough fancy and figured weaves. Harness draft and chain are worked out for each weave. Yarn numbering for all systems, including ply and fancy yarns.

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COTTON AND ORLON BLENDS IN YARNS

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INTRODUCTION

This bulletin is based upon work done under the direction of the author by Binod Nair in his major project as a partial requirement for his B.S. degree in Textile Manufacturing. This work covered the phase of blending a natural and a man-made fiber as a sandwich blend previous to picking, processing into yarns of the same count using a variety of twists, and some evaluation of those yarns.

PURPOSE

The purposes of this work were:

1. To process cotton and Orlon fiber into blended yarns containing the following blends:
   - I. 100% Orlon
   - II. 75% Orlon — 25% cotton
   - III. 50% Orlon — 50% cotton
   - IV. 25% Orlon — 75% cotton
   - V. 100% cotton
2. To determine the effect of blend composition on some of the physical characteristics of the yarn.
3. To determine the effect of twist on some of the physical characteristics of the blended yarns.

FIBERS USED

The cotton used was 1¼-inch Middling grade having a fineness of 4.1 micrograms per inch. The specific gravity was about 1.54 and the elongation at break from 3 to 7 percent [1]. The Orlon used was 1½-inch, 3-denier, type 42, semi-dull, crimped, with a specific gravity of 1.14, and elongation at break from 20 to 28 percent [1].

PROCEDURE

The cotton was cleaned before blending by running it through a cleaning line consisting of a blending feeder, No. 11 condenser, No. 12 lattice opener, No. 11 condenser, then through a Saco-Lowell C-2 picker to produce a 13½-ounce lap. This removed 1.5 percent of waste.

Sandwich blends were made up of the cleaned cotton and the Orlon according to the previously mentioned proportions on a weight basis. Each blend was run through the blending feeder, then through the blending reserve and finisher section of the picker twice to produce approximately 14-ounce laps. The all-cotton blend was not rerun through the picker. The following organization of drafts and sizes was followed in processing the blends into yarn:

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Picker lap	13½ ounces per yard
Card draft	110
Card sliver	50 grains per yard
First drawing doublings	8
First drawing draft	8
First drawing sliver	50 grains per yard
Second drawing doublings	8
Second drawing draft	8
Second drawing sliver	50 grains per yard
Roving doublings	1
Roving draft	16.1
Roving produced	2.80 hank
Spinning doublings	2
Spinning draft	15.0 (including 5% twist contractio
Yarn (cotton count)	20^s

The following twist multipliers were used for each blend in spinning: 2.75, 3.00, 3.25, 3.50, 4.00, 4.50, and 5.50.

A.S.T.M. Committee D-13 procedures were followed for testing wherever applicable after conditioning the yarns for at least 24 hours at 70° F. and 65% relative humidity. The following tests were run:

1. Skein tests
   Two 120-yard skeins were reeled from each of six bobbins and broken on a Scott pendulum tester (Type J).
2. Single-strand tests
   Five 10-inch specimens from each of six bobbins were broken on a Scott IP-2 inclined-plane tester.
3. Yarn size
   The weights of the broken 120-yard skeins were determined, and resulting cotton count was calculated.
4. Twist determinations
   Thirty twist counts were made on each yarn, five tests on each of six bobbins and taken at least one yard apart. The untwist-twist method was used on a 10-inch specimen length with 7.8 grams initial tension.
5. Elongations at break
   These were determined from the charts obtained from the single-strand breaks and converted to percentages.
6. Yarn appearance
   Yarns from all of the blends having twist multipliers of 3.25 and 3.5(were wound onto 8 inch x 5 inch blackboards with 25 wraps per incl and were then compared to Cotton Yarn Appearance Standards anc graded.
7. Yarn diameter
   Yarn was suspended just over the stage of the microscope between tw(spooler disc-type tension devices, and readings were taken with the fila micrometer. The tension on the yarn was only sufficient to hold i straight. Measurements were made on the blends consisting of 100% Orlon (I), 50-50 Orlon and cotton (III), and 100% cotton (V) havin 3.00, 4.00, and 5.50 twist multipliers. Sixteen readings were taken fron each of five bobbins, and twenty readings were taken from the sixtl bobbin. Readings were taken at least one yard apart.

RESULTS

Wastes in processing

Blending feeder waste was mostly in the form of bunches of Orlon and of cotton fibers. The blending reserve waste consisted mainly of bunches of unopened Orlon fiber. The Kirschner beater waste contained some leaf and dust with a few fibers, especially with relatively large amounts of cotton in the blend. Licker in waste when processing blends containing cotton (II, III, IV, and V) consisted mostly of motes and leaf trash. The waste was dirtier as the amount of cotton in the blend increased. Both Orlon and cotton fibers were in flat, cylinder, and doffer strips.

Processing difficulties encountered

Blends containing higher percentages of Orlon (I and II) had a greater tendency to lap splitting at the card. A lighter lap was preferred, but the necessary adjustment on the picker was lacking. There was a tendency for the card webs to sag on these two laps; also more difficulty with static was encountered at drawing. All blends containing cotton were run with the same roving twist multiplier, 0.83, and the all-Orlon blend (I) was run with a lower twist multiplier of 0.75. More end breakage was experienced with the blends of high Orlon content (I and II) when spinning with the higher twist multipliers.

Test results

Test results are given in the tables and diagrams on the following pages.

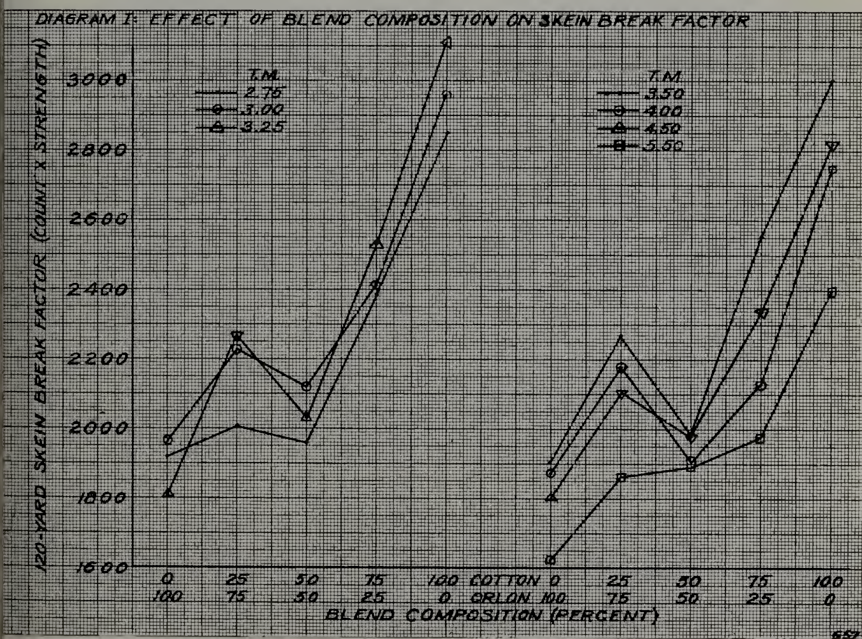


DIAGRAM I: EFFECT OF BLEND COMPOSITION ON SKEIN BREAK FACTOR

Table I

Twist, Size, Break, and Elongation

Theoretical Twist Multiplier	Actual Twist Multiplier	Cotton Count	Denier	Skein Break (pounds)	Single Strand: Break (grams)	Single Strand: Break (pounds)	Single Strand: Break Factor	Single Strand: Elongation at Break
100% Orlon								
2.75	2.96	20.3	262.1	94.6	397.7	0.88	17.8	18.31
3.00	3.09	20.7	256.6	94.9	408.7	0.90	18.6	19.06
3.25	3.39	18.9	280.8	95.9	406.2	0.89	16.8	18.98
3.50	3.58	19.7	270.0	96.6	432.7	0.95	18.8	18.09
4.00	3.95	19.4	273.8	96.6	420.8	0.93	18.0	18.70
4.50	4.32	19.0	279.7	94.9	433.8	0.96	18.2	19.50
5.50	5.45	18.9	280.8	86.1	400.2	0.88	16.6	19.35
75% Orlon — 25% Cotton								
2.75	2.87	20.4	261.1	98.4	359.2	0.79	16.1	6.56
3.00	3.06	21.0	253.1	106.5	351.9	0.78	16.3	6.63
3.25	3.17	20.5	258.1	110.5	402.0	0.89	18.2	7.09
3.50	3.55	21.1	252.2	107.5	387.3	0.85	18.0	6.84
4.00	4.02	20.1	265.7	108.5	405.1	0.89	17.9	7.15
4.50	4.38	19.6	270.6	107.9	435.7	0.96	18.9	7.36
5.50	5.54	18.9	280.8	98.6	387.8	0.86	16.1	8.04
50% Orlon — 50% Cotton								
2.75	2.80	20.8	254.5	94.1	298.3	0.66	13.6	6.27
3.00	3.07	20.6	257.0	103.1	353.6	0.78	16.1	6.32
3.25	3.39	20.4	261.1	99.7	326.4	0.72	14.6	6.56
3.50	3.62	20.5	258.2	96.6	345.6	0.76	15.6	6.51
4.00	4.10	19.3	274.9	98.7	365.4	0.80	15.6	6.74
4.50	4.39	19.4	273.8	101.8	385.0	0.85	16.3	6.93
5.50	5.60	19.5	271.9	97.2	359.4	0.79	15.4	7.60
25% Orlon — 75% Cotton								
2.75	2.96	19.1	279.0	125.0	355.8	0.78	15.0	6.67
3.00	3.19	19.3	274.9	125.0	427.1	0.94	18.1	6.73
3.25	3.48	19.2	277.5	131.6	412.7	0.91	17.5	6.98
3.50	3.79	18.9	280.8	134.9	459.6	1.01	19.1	6.89
4.00	4.33	17.7	300.0	120.4	447.4	0.98	17.4	7.64
4.50	4.71	18.0	295.3	130.1	431.0	0.95	17.1	6.68
5.50	6.03	16.8	316.6	118.1	408.6	0.90	15.1	8.25
100% Cotton								
2.75	2.87	19.9	265.7	143.4	465.2	1.02	20.4	7.26
3.00	3.09	20.4	261.1	144.9	491.2	1.08	22.0	7.11
3.25	3.29	19.6	270.6	159.0	524.3	1.15	22.6	6.50
3.50	3.71	19.7	270.0	152.0	529.0	1.17	23.0	6.40
4.00	4.29	19.0	279.7	144.9	524.0	1.16	22.0	8.03
4.50	4.39	18.7	284.7	150.9	548.2	1.21	22.6	6.72
5.50	5.76	18.2	291.8	132.2	515.0	1.14	20.7	9.25

Table II

Yarn Diameter, Specific Volume, Bulk Density, and Packing Coefficient

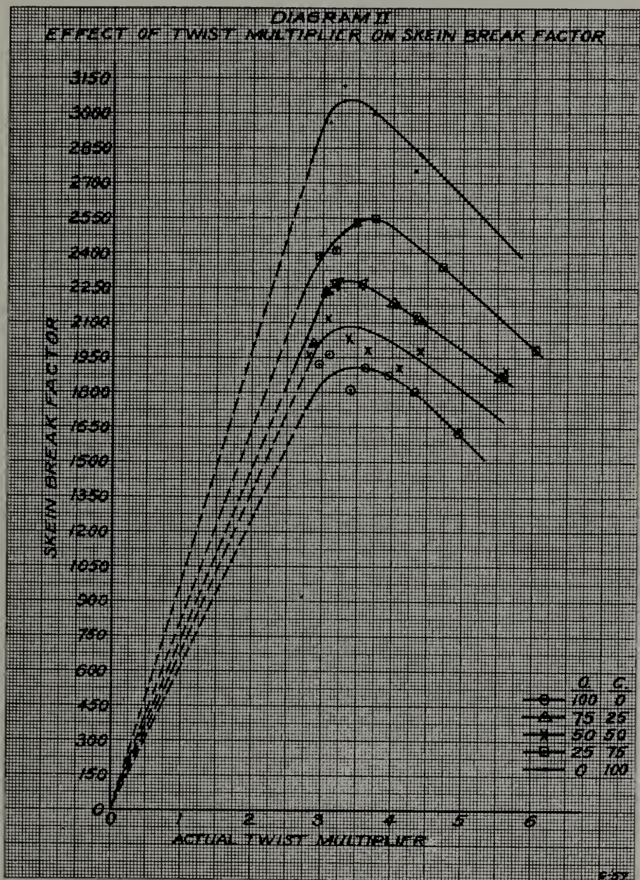
Theoretical Twist Multiplier	Item	Blend (Percent): 100% Orlon 0% Cotton	50% Orlon 50% Cotton	0% Orlon 100% Cotton
3.00	Actual T. M.	3.09	3.07	3.09
	Actual count	20.7	20.6	20.4
	Actual diameter (inches)	.00954	.00961	.01055
	Diameter corrected to 20^s	.00969	.00975	.01065
	Specific volume	1.618	1.640	1.945
	Bulk density	.618	.610	.514
	Packing coefficient	.538	.463	.334
4.00	Actual T. M.	3.95	4.10	4.29
	Actual count	19.4	19.3	19.0
	Actual diameter (inches)	.00885	.00899	.00897
	Diameter corrected to 20^s	.00975	.00882	.00832
	Specific volume	1.308	1.342	1.318
	Bulk density	.765	.745	.760
	Packing coefficient	.666	.566	.494
5.50	Actual T. M.	5.45	5.60	5.76
	Actual count	18.9	19.5	18.2
	Actual diameter (inches)	.00868	.00844	.00835
	Diameter corrected to 20^s	.01065	.00875	.00797
	Specific volume	1.222	1.192	1.090
	Bulk density	.818	.841	.920
	Packing coefficient	.712	.640	.597

DISCUSSION

Breaking strength

The usual effect of increase of twist multiplier on spun staple yarns was observed (see Diagrams II and IV). The all-Orlon blend reached its maximum strength with a twist multiplier of approximately 3.25. This was a slightly higher twist multiplier than the 2.9 to 3.1 twist multipliers recommended by the fiber producer [2]. Also this yarn was a little weaker than suggested by the fiber producer for a similar count yarn from similar fiber.

There was a decided disagreement in the relative strength of the all-Orlon-blend yarns compared to the strength of other blends depending upon the



method of strength evaluation. The skein-test method indicated they were the weakest yarns (see Diagrams I and II), whereas the single-strand method indicated that they were the next to the strongest yarns (see Diagrams III and IV). Actually there was a fundamental difference in test conditions. Since the single-strand tests were performed on an IP-2 tester having a constant rate of loading, the strength results depended solely on the inherent yarn strength. The skein breaks were done on a pendulum-type tester wherein the recorded breaking strength is influenced by the rate of loading, which in turn is dependent upon

the elongation of the yarn. Because the Orlon had a high elongation, it induced a slower rate of loading resulting in an apparent lower breaking strength for this method of test. The possibility that this high elongation may have affected the results on the single-strand breaks is also recognized.

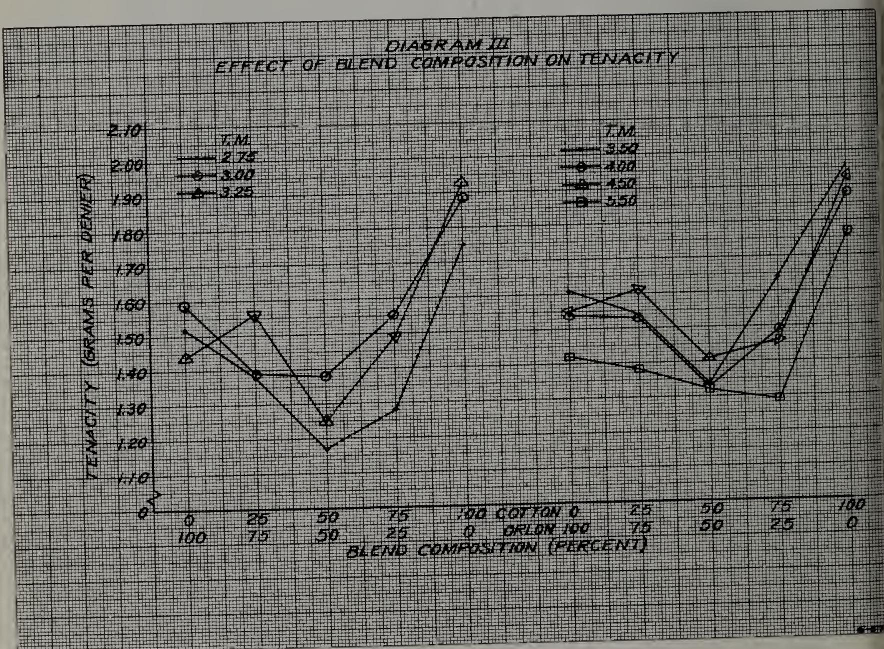
The interchange of relative strength positions as a result of test methods was also observed in blends of 75 percent Orlon and 25 percent cotton in the same relative direction.

The all-cotton blend produced the strongest yarn from the stronger fiber. As the amount of Orlon in the blend was increased, there was a sharp decrease in yarn strength until approximately equal amounts of both Orlon and cotton were present, then an increase in strength resulted with additional amounts of Orlon in the blend. Since the cotton fiber has a breaking elongation ranging from 3 to 7 percent as compared with 20 to 28 percent for Orlon [1], the cotton fibers present in the blends containing both cotton and Orlon were loaded to the breaking point before the Orlon fiber assumed its proportionate share of the load, thereby resulting in a relatively low breaking strength.

Elongation at the break

The all-Orlon blend had the highest elongation, and the all-cotton blend had less elongation, which was expected because there was such a difference in the respective fiber elongations. The blends containing a mixture of both fibers had less elongation than either of the 100-percent blends, and the 50-50 blend had the lowest elongation (see Diagram V). This again emphasized the importance of the respective elongations of the component fibers; in these cases the Orlon fiber was the "shirking" fiber that did not carry its proportionate share of the load, so an early break was achieved.

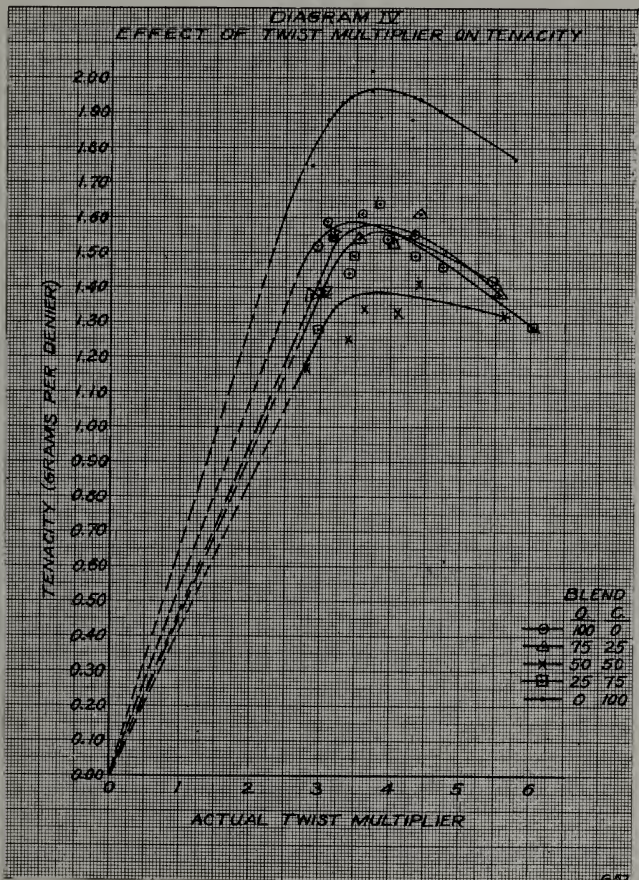
Higher twists resulted in greater elongation (see Diagram VI).



Appearance

The blends containing both fibers produced the neppier yarns. The more cotton in the blend, the greater the neppiness. The reason for there being more neps in these yarns than in the all-cotton blend was probably the additional mechanical action on these fibers during blending, since the cotton in this stock had two extra passages through the finisher picker.

The blend containing 25 percent Orlon and 75 percent cotton was the most uneven yarn. This might be anticipated, because there were relatively few long Orlon fibers to control the large number of shorter cotton fibers, especially in the drawing operations where the rolls had to be set to accommodate the longer fibers. Further, some difficulties were encountered because of an occasional splitting of the lap at the card and static during one of the drawing processes resulting from a temperature lower than normal. The rolls were set closer for the 100-percent cotton, which resulted in a yarn of more even appearance.



Packing coefficient

The packing coefficient represents the percent of fiber space in a yarn, expressed decimally. Since the blends containing Orlon have the higher packing

coefficients, with the all-Orlon blend having the highest, these yarns are more compact and less lofty than the all-cotton yarn with a similar twist multiplier (see Diagram VII). The packing coefficient increased with an increase in twist multiplier, which in turn bound the fibers more tightly together.

Yarn diameter

For a given low twist multiplier the blends containing higher amounts of Orlon had the smaller diameters. For medium twist multipliers there was little difference in yarn diameter with changes in blend percentages. When high twist multipliers were used, producing more compact yarns, the Orlon blends had the larger yarn diameter (see Diagram VII). Corrections were not made in yarn diameters for small variations in twist from one blend to another, which may be a source of some error. Corrections were made for variations in count.

For a given packing coefficient, 0.540 in this case, the yarns would have the same amount of air space and can be compared for relative diameters. The all-Orlon had the largest diameter, the 50-50 blend was next, and the all-cotton blend had the least. This conforms with the fiber densities (see Diagram VIII) in that the less dense fiber produces the larger-diameter yarn. A lower twist multiplier was needed for the all-Orlon blend than for the all-cotton or combinations of both fibers in the case of this packing coefficient.

Specific volume

The specific volume is the ratio of the volume of a given weight of a material to the volume of an equal weight of water and may be computed from the yarn diameter. The curves in Diagram VII indicate the agreement between these two factors.

For a given packing coefficient the all-Orlon blend had the greatest specific volume, the all-cotton blend had the least, and the 50-50 blend was half-way between (see Diagram VIII).

It is further interesting to note that the diameter of an all-cotton yarn with a specific volume of 1.1 agrees with the values of F. T. Pierce, and the corresponding packing coefficient is close to Pierce's also [3].

Determinations for actual blend content in the yarn have not been made, nor have the samples of processing wastes been analyzed for specific amounts of a given type of fiber.

CONCLUSIONS

Effect of blend composition on:

1. Breaking strength of the yarn
   a) The method of determining the breaking strength had an important bearing on the results where high elongation at the break existed.
   b) On the basis of skein-break tests for a given twist multiplier:
      (1) The all-cotton blend was the strongest.
      (2) The all-Orlon blend was the weakest.
      (3) Of the blends containing both Orlon and cotton the one containing approximately equal amounts of both fibers was the weakest, the one with a predominance of Orlon was stronger, and the one with a predominance of cotton was still stronger.

c) On the basis of single-strand tests:

  (1) The all-cotton blend was the strongest.

  (2) The all-Orlon blend was somewhat weaker than the all-cotton blend but next to it in order of magnitude for twist multipliers less than 3.65.

  (3) Of the blends containing both cotton and Orlon fiber the one containing 75 percent Orlon and 25 percent cotton was stronger than the 25 percent Orlon-75 percent cotton blend, and the 50-50 blend was the weakest of all those tried.

2. Elongation at the breaking point

   a) The all-Orlon blend had the greatest elongation at the break of all blends run. This was approximately twice that of blends containing cotton fibers.

   b) Blends containing cotton fibers had approximately the same elongation at the break. In general there was a decrease in the ultimate elongation to about the 50-50 blend point and then a small increase to that of the all-cotton blend.

3. Yarn appearance

   a) The all-Orlon blend was the best-appearing yarn and graded as "A".

   b) Blends containing both Orlon and cotton produced neppy yarns. The greater the amount of cotton present, the neppier the resulting yarn. These were graded from "B" to "C".

   c) The all-cotton yarn had fewer neps than the blends containing both cotton and Orlon and was graded "B".

4. Packing coefficient

   For a given twist multiplier the all-Orlon blend had the highest packing coefficient. This decreased as the amount of cotton in the blend increased, and attained a minimum value with the all-cotton blend.

5. Yarn diameter (20^{s} cotton count)

   a) For low twist multipliers the all-Orlon blend produced the smaller-diameter or less lofty yarn. This apparently did not change very much until large amounts of cotton were used.

   b) For medium twist multipliers there was little change in diameter as the relative amounts of fiber were varied.

   c) For high twist multipliers the larger-diameter yarns contained larger amounts of Orlon fiber, and the all-cotton blend had the smallest diameter.

   d) For a given packing coefficient the all-Orlon blend had the largest diameter and the all-cotton blend had the smallest. The diameter decreased with increasing amounts of cotton.

6. Specific volume

   a) For a given twist the specific volume changes the same as the yarn diameters as the blend composition is varied.

   b) For a given packing coefficient the specific volume was greatest for the all-Orlon yarn and diminished as the amount of cotton was increased to the all-cotton blend. This was similar to the change in yarn diameter.

Effect of twist multiplier on:

1. Breaking strength of the yarn
   a) As the twist multiplier increased there was an increase in strength up to a certain point and then a decrease. The rate of increase was greater than the rate of decrease within the range of twist multipliers investigated.
   b) Maximum strength was attained when using twist multipliers between 3.25 and 3.85. Approximately 3.25 was used for the all-Orlon blend and somewhat higher ones were used for the all-cotton and the cotton-Orlon blends.

2. Elongation at the break
   For a given blend there was an increase in the elongation at the break as the twist multiplier was increased.

3. Packing coefficient
   a) There was an increase in the packing coefficient with an increase in twist multiplier for a given blend.
   b) To maintain a given packing coefficient it was necessary to use a higher twist multiplier as the amount of cotton in the blend was increased.

4. Yarn diameter
   There was a decrease in yarn diameter with an increase in twist multiplier.

5. Specific volume
   The specific volume decreased with an increase in twist multiplier, similar to the yarn diameter.

FORMULAS USED FOR CALCULATIONS

$$\text{Break Factor} = (\text{Yarn-breaking Strength in Pounds})\ (\text{Yarn Count})$$

$$\text{Tenacity} = \frac{\text{Single-Strand Break in Grams}}{\text{Denier of Yarn}}$$

$$\text{Yarn Diameter Corrected to } 20^{s} = \frac{\text{Measured Diameter } \sqrt{\text{Actual Count}}}{\sqrt{20^{s}}}$$

$$\text{Specific Volume} = (858)\ (\text{Cotton Count})\ (\text{Diameter})^2$$

$$\text{Bulk Density} = \frac{1}{\text{Specific Volume}}$$

$$\text{Packing Coefficient} = \frac{\text{Bulk Density}}{\text{Fiber Density}}$$

$$\text{Fiber Density of Blend} = \frac{100}{\dfrac{\text{Percent Fiber A}}{\text{Density Fiber A}} + \dfrac{\text{Percent Fiber B}}{\text{Density Fiber B}}}$$

$$\text{Denier of Cotton} = (\text{Micrograms per Inch})\ (.354)$$

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3. Pierce, F. T., "Geometry of Cloth Structure." *Journal of the Textile Institute,* 28, T45-96 (March 1937).

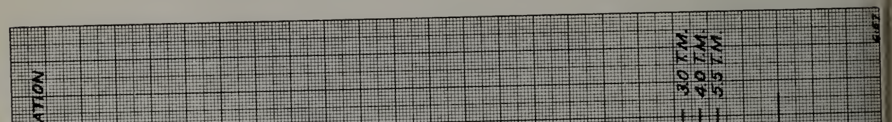

DIAGRAM V
EFFECT OF BLEND COMPOSITION ON ELONGATION AT BREAK
ELONGATION (PERCENT)
20
18
16
14
12
10
8
6
4
2
0
COTTON 0 25 50 75 100
ORLON 100 75 50 25 0
BLEND COMPOSITION (PERCENT)
3.0 T.M.
4.0 T.M.
5.5 T.M.

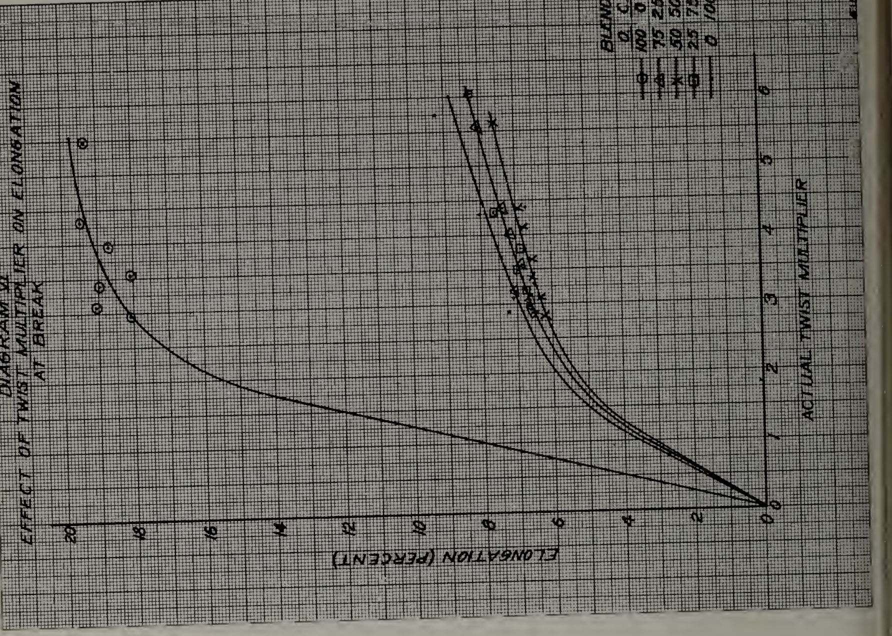

DIAGRAM VI
EFFECT OF TWIST MULTIPLIER ON ELONGATION AT BREAK
ELONGATION (PERCENT)
20
18
16
14
12
10
8
6
4
2
0
0 1 2 3 4 5 6
ACTUAL TWIST MULTIPLIER
BLEND
O C
100 0
75 25
50 50
25 75
0 100

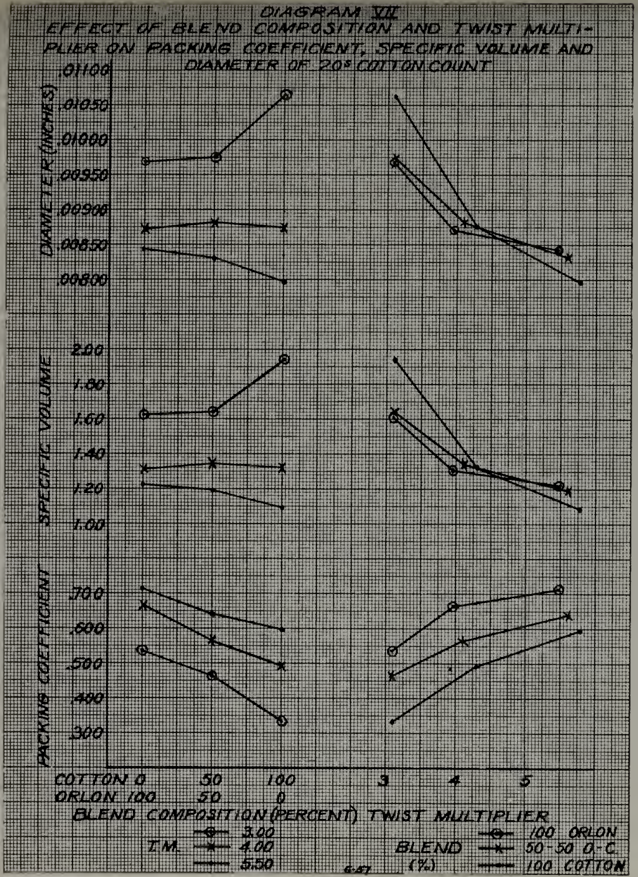
DIAGRAM VII
EFFECT OF BLEND COMPOSITION AND TWIST MULTIPLIER ON PACKING COEFFICIENT, SPECIFIC VOLUME AND DIAMETER OF 20s COTTON COUNT
DIAMETER (INCHES)
.01100
.01050
.01000
.00950
.00900
.00850
.00800
SPECIFIC VOLUME
2.00
1.80
1.60
1.40
1.20
1.00
PACKING COEFFICIENT
.700
.600
.500
.400
.300
COTTON 0 50 100
ORLON 100 50 0
BLEND COMPOSITION (PERCENT)
3 4 5
TWIST MULTIPLIER
T.M. 3.00 4.00 5.50
BLEND (%) 100 ORLON 50-50 O-C 100 COTTON
6-57

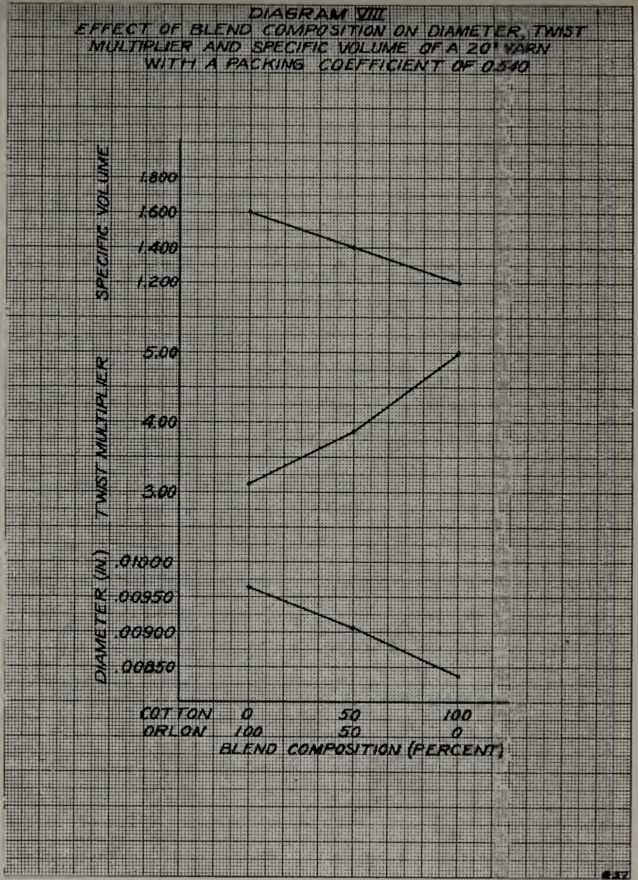
DIAGRAM VIII
EFFECT OF BLEND COMPOSITION ON DIAMETER, TWIST MULTIPLIER AND SPECIFIC VOLUME OF A 20s YARN WITH A PACKING COEFFICIENT OF 0.540
SPECIFIC VOLUME
1.800
1.600
1.400
1.200
TWIST MULTIPLIER
5.00
4.00
3.00
DIAMETER (IN.)
.01000
.00950
.00900
.00850
COTTON 0 50 100
ORLON 100 50 0
BLEND COMPOSITION (PERCENT)

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STUDIES OF THE STRUCTURE OF BARIUM TITANATE WITH THE ELECTRON MICROSCOPE*

DR. CHARLES R. MINGINS† *and* ROBERT W. PERRY‡

ABSTRACT

Barium titanate ceramic in the form of fired disks, thin ribbon, and thin plates cut from the disks is investigated with the electron microscope. The reasons for the apparent manner of grain crystallization are examined.

INTRODUCTION

In most electron microscope studies there are rather special problems peculiar to each case; the study of barium titanate ceramic is no exception to this. In the first place, of course, it is impossible to cut sections of the material thin enough for use as specimens, and therefore it is necessary to make replicas of the surface. Furthermore, in comparing exterior fired surfaces with surfaces obtained from the interior, different replicating methods are called for.

TECHNIQUES OF REPLICATION

We very early found that the cut and lapped surface of a ceramic plate from the interior presents a very rough aspect, with many deep crevices, as the electron micrograph of Fig. 1 shows. From such a surface it is impossible to strip ordinary Formvar film because of the penetration of the film material into the deep irregular fissures. It was therefore found necessary to develop a special technique[1] for use with such surfaces. This involves the use of an adhesive with the Formvar to seal down the fine-mesh grid to the Formvar film. The whole can then be stripped away by the use of cellophane tape as is done in the usual case. After stripping, however, one must dissolve the adhesive in order that the total replica structure shall not be too thick. This can be done with impunity because there is still the natural adhering tendency of the Formvar for the grid. Polystyrene cement has been used with some success as an adhesive in this method.

Alternative to the adhesive technique is the use of polyethylene, which can be warmed and pressed against the ceramic surface. There are two difficulties with this method. First, the limited ability of the polyethylene to penetrate into the crevices gives a false replication of much of the region under examination; and second, the method is more indirect, inasmuch as a second replica has to be made of the polyethylene surface.

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*Part of this research was carried out while the authors were staff members at Tufts University. The investigation has been sponsored by the U. S. Office of Ordnance Research under contract No. DA-19-020-ORD-2568 with Tufts University and contract No. DA-19-020-ORD-4347 with the Lowell Technological Institute Research Foundation.

†Chairman, Division of Engineering, Lowell Technological Institute.

‡Research Associate, Lowell Technological Institute Research Foundation.

OBSERVATIONS ON CERAMIC PLATES

One characteristic of a surface which has been cut and lapped is the abundance of broken material which is lying about. Some of this material can be removed by a preliminary process of stripping off cellophane tape. Much of it, however, persists in staying in place, probably because of the cohesive forces for the main body of the specimen. A process of etching will remove some of the debris and help to clean up the surface for observation, but Fig. 2 indicates that the general aspect is a rather complicated one and it is difficult to make out the grain boundaries. Furthermore, if etching is carried beyond a certain point, as in Fig. 3, the boundaries between grains tend to be obscured by a removal process so that one obtains an exaggerated impression of the size of these grains.

A natural fired surface is more readily investigated by the ordinary Formvar technique, and Fig. 4 shows an electron micrograph of such a surface. A very striking impression that one gains from this picture concerns the range of grain

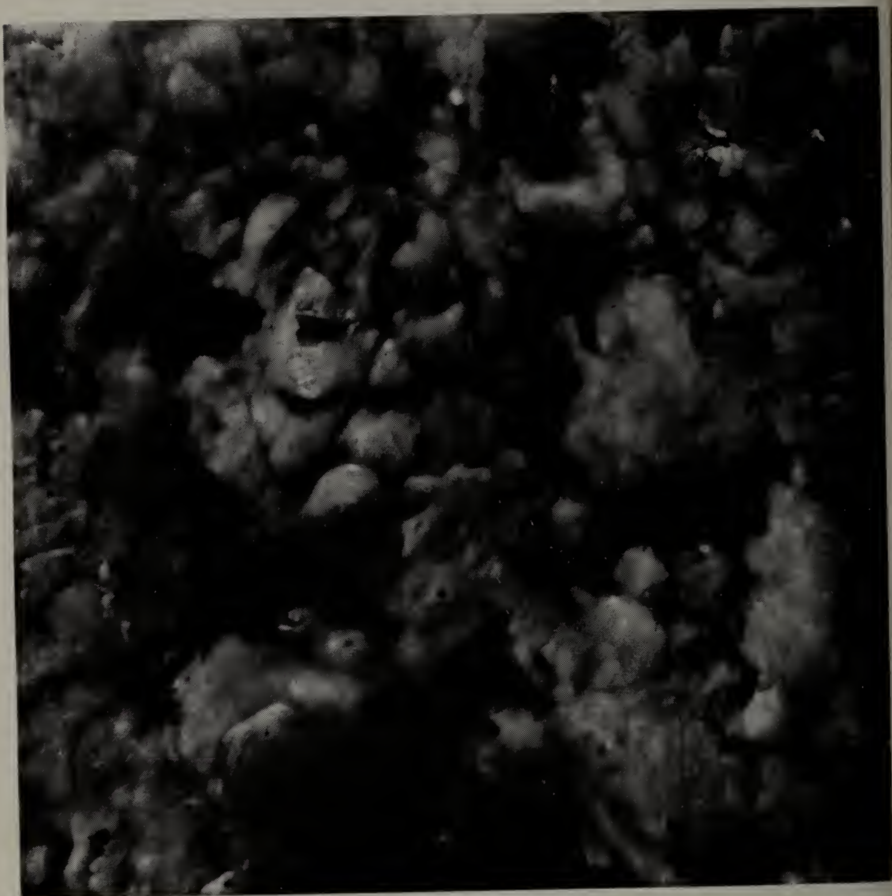

FIGURE 1—Barium titanate ceramic. Lapped surface. Surface material is rough. Deep cavities are numerous.

Negative Formvar replica stripped with the aid of polystyrene adhesive. Shadowcast, Inconel. (× 4,000)

sizes. Such a range seems to be necessary in the manufacture of a homogeneous product. If one looks in particular at the largest grain shown in this picture, there seems to be evidence that a coalescence has taken place such that this grain is the result of a merging of smaller grains. The grains in a surface picture seem to come out somewhat larger than those in the interior; this may indicate that coalescence occurs more readily at the surface.

The size of the grains in the finished material is a matter of some importance. If the wavelength of the energy being transmitted in the material, whether from an outside source or stimulated internally, is large compared to the grain size, the transmission process will involve scattering, and energy scattered will be proportional to the square of the grain volume and inversely proportional to the fourth power of the wavelength. Mason[2] has shown that for a range of grain sizes the effective volume in this respect comes out larger than the simple average volume. On the other hand, if the wavelength is small compared to the particle dimension, the process of energy transfer is one of diffusion

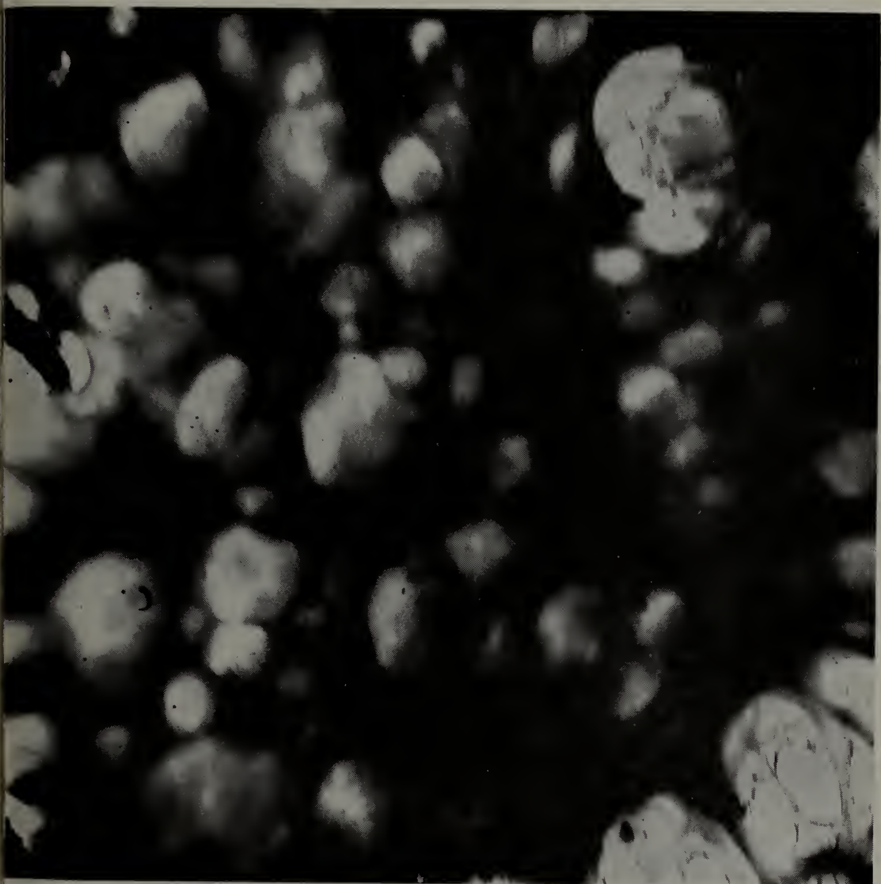

Figure 2—Lapped surface after some etching. Much of it still out of focus, but a lot of the debris has been removed.

Negative Formvar replica stripped with the aid of polystyrene adhesive. Shadowcast, Inconel. (× 3,000)

in which the energy losses will be inversely proportional to the mean free path. The free path in any granule should be the "diameter" of the granule, at least if the wavelength remains large compared to atomic dimensions.

Another outstanding detail appearing in Fig. 4 is the number of small striae shown. Actually the striae turn out to be terraces, and the pictures obtained, such as this one, are reminiscent of Wyckoff's photographs of Rothamsted protein[3]. Wyckoff called his pictures early stages of growth in which the crystal would fill out to the edges after a sufficient time. However, this point of view would hold only if the crystal were being grown in the presence of an abundant source of potential crystallizable material, as, for example, in solution. In the case we are studying, the necessary additional material is not available. For the fired ceramic we have undoubtedly a surface tension effect, and one can see

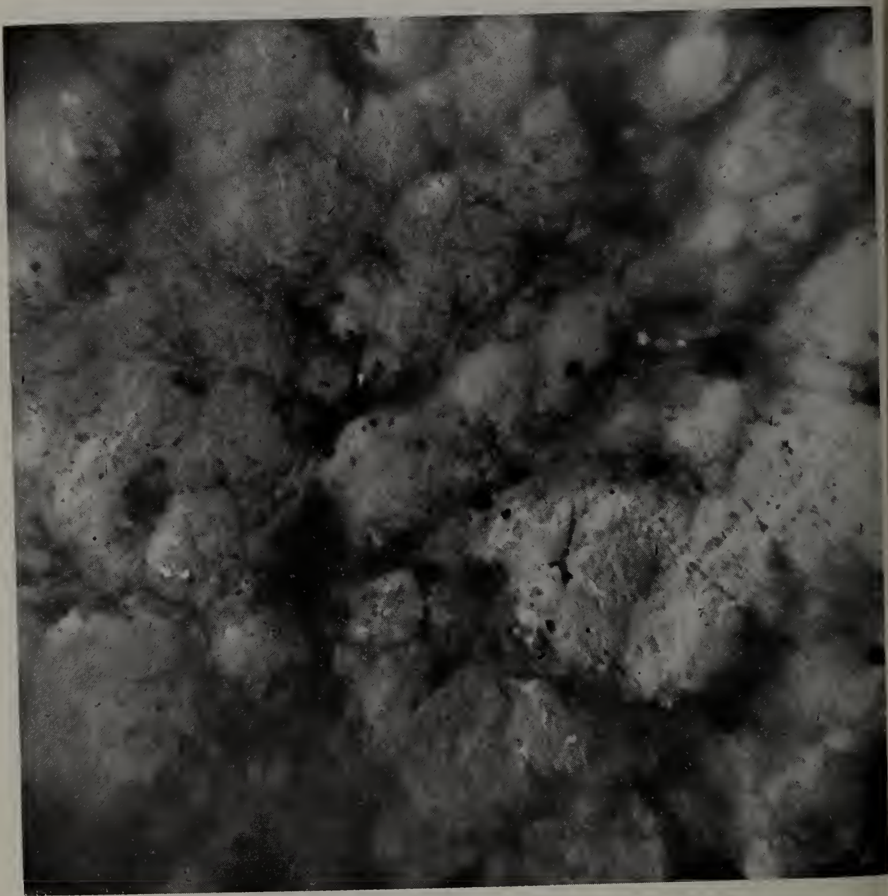

FIGURE 3—Barium titanate ceramic. Etched surface. The softened appearance has been produced by the action of further etch in rounding the edges of the particles. Negative Formvar replica stripped with the aid of polystyrene adhesive. Shadowcast, Inconel. (× 3,000)

evidence in the terraces of a contest between the rectilinear tendencies of the crystallization process and the curvilinear tendencies of surface tension or general cohesion effects. In other words, here is a conflict between nature's economy of surface and the orderliness of crystal formation. A further feature which may be noticed in this picture is the randomness of the crystalline orientations in different grains as exhibited by the directions in which the terrace caps point.

It seems clear from the irregular form of these terraces that the growth of each layer began somewhere in the interior of the layer below it, rather than at the corners and edges of that layer as called for by the theories of Kossel[4] and of Stranski[5] for ionic crystals. Apparently we have here evidence of a Frank-Read type of source[6] consisting of two screw dislocations with equal and opposite slip vectors so that the two end points project to form an interior step upon

Figure 4—Barium titanate: a natural fired surface showing the wide range of grain sizes. The striae are crystal growth terraces.

Formvar negative replica. Shadowcast, chromium. ($\times$ 4,800)

which the new face can grow. The occurrence of such a source in natural beryl was shown by Griffin's beautiful phase-contrast micrograph[7].

OBSERVATIONS ON RIBBON

Figure 5 shows an electron micrograph of the surface of thin barium titanate ribbon*. The thickness of this ribbon is about 0.002 inch, and, needless to say, it is exceedingly fragile. Another special replicating method was therefore found necessary: this technique involves "floating" the ribbon on the surface of water where it is supported by the surface tension of the water. A Formvar film is then applied, and when the screens are dropped on the Formvar, the separation of the Formvar from the titanate is very easily brought about. In fact, sometimes when the screens are dropped on, if one is lucky, the ribbon falls away from the Formvar into the water. Occasionally water drops become trapped in the film,

*Prepared by Glenco Corporation.

FIGURE 5—Barium titanate ribbon. Variations in grain size shown. Formvar negative replica. Shadowcast, chromium. (× 4,800)

but such intruders are readily identifiable. The picture here shows the terraced character of the ordinary grains, but a clearer idea is given by the micrographs of Figs. 6 and 7, made with considerably higher magnification.

The preparation of the thin ribbon, which is fired at about 1500° C., apparently offers an excellent chance for the formation of more complete crystals as is shown by the much further advanced structure of Fig. 8. This one could be referred to as a Mayan temple or a truncated pyramid, and an instance of the same type of formation with very regular steps is shown in Fig. 9. In this sort of growth the crystal probably filches material from its neighbors to grow to a more mature form. The probability that such is the process is enhanced by the fact that these crystals are surrounded by the more incomplete granules and therefore that they probably act as acquisitive centers. The more perfect structure, once under way, cools faster because of the more rapid use of energy and hence reaches its higher degree of perfection at the progressive expense of its neighbors.

The temporary temperature difference between the more advanced crystal and those surrounding it, although exceedingly minute, seems to be the key to

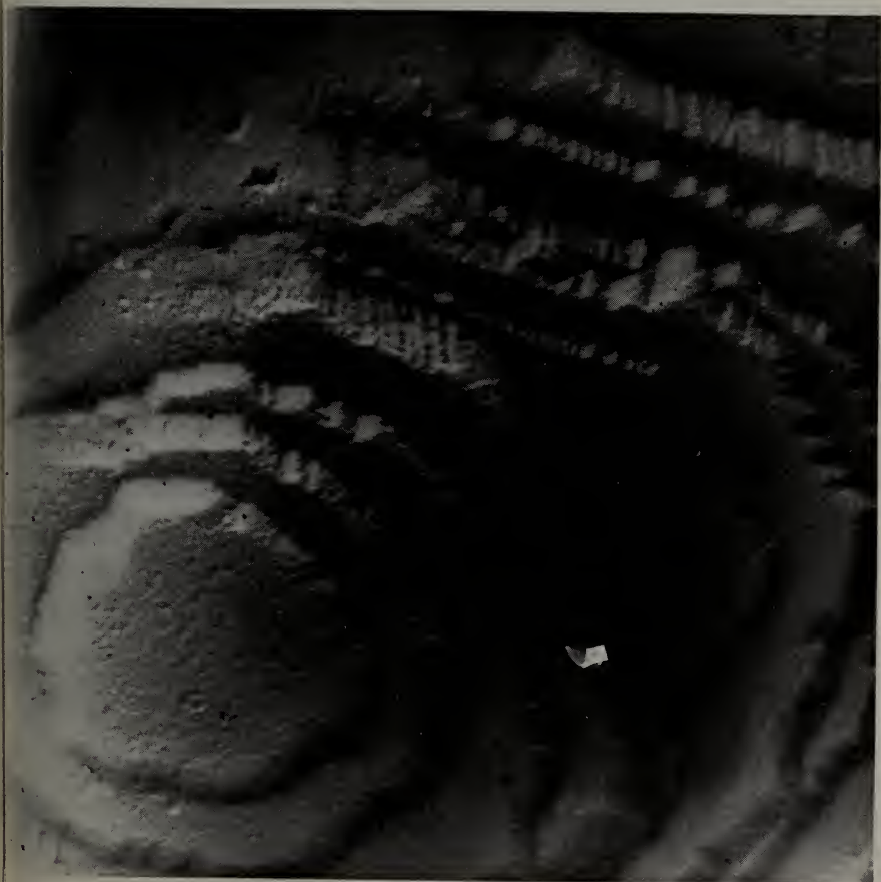

FIGURE 6—Ribbon surface. This picture shows the terraced cap of a crystal grain. Formvar negative replica. Shadowcast, chromium (× 27,000)

the differential process. If it can be assumed that a certain critical diffusion velocity V_c must be exceeded to enable atoms to migrate across the intergrain boundaries, it can be shown with the help of Fig. 10 that the end result of the cross-boundary traffic would be a large net gain in energy by the cooler crystal. Figure 10 shows the general form of the kinetic-theory velocity distribution curves for two temperatures, T_1 and T_2, representing the number of diffusion particles having any given velocity in the more advanced crystal and in the surrounding ones, respectively. The difference between the mean velocities in the two instances is not great, yet there are a great many more particles having velocities in excess of V_c represented on the T_2 curve than on the T_1 curve. Consequently, according to this theory, the higher-velocity atoms from the warmer surrounding material are responsible for providing the energy which according to the theories of Curie[8], Gibbs[9], and others[10] must be expended in increasing the surface of the more advanced crystal; the process is therefore a cumulative one. It must be remembered, however, that the surrounding grains are losing their fastest atoms. The whole process, then, takes place very rapidly

FIGURE 7—Ribbon surface. Another terraced cap showing fairly uniform recession of growth layers.

Formvar negative replica. Shadowcast, chromium. (× 31,000)

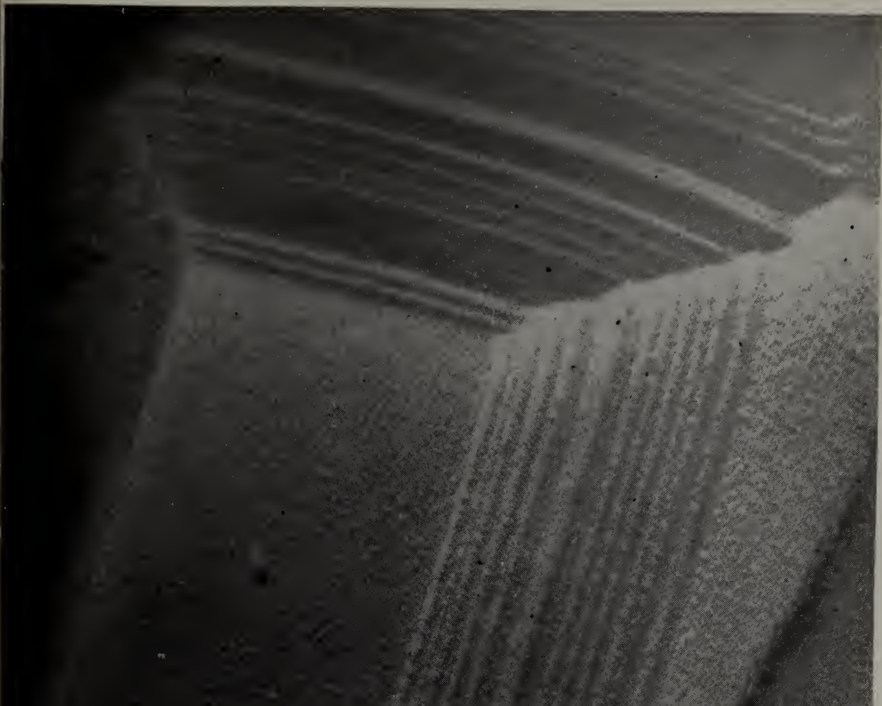

FIGURE 8—Barium titanate ribbon surface. Some rather complete crystals are found in this thin ribbon material. The truncated pyramid (Mayan temple) shown here is an example.

Formvar negative replica. Shadowcast, chromium. (× 45,000)

once under way, which means the growth atoms have to "step lively" to produce fruitful encounters, and V_c is properly chosen well up on the curves, as shown. Here again the growth of a layer obviously does not begin at the corners or edges of the previous layer, whence dislocations of a double-spiral nature must still be postulated.

If one objects to departures—however minute they may be—from an isothermal process, it is possible to postulate a system in which a corresponding fortuitous difference in strain energy occurs in certain grains, leading to a similar cumulative upset in which only these grains complete or nearly complete their growth.

Figure 11 shows a stepped structure plus two complete pyramids and a third incomplete one. There is also a suggestion of more step lines which would need a higher resolution to show. It is of interest that Forsbergh[11] inferred from birefringence observations that laminated pyramids constitute a form of growth of barium titanate crystals.

FIGURE 9—Barium titanate ribbon surface. A quite uniform structure of steps along the edge of a partial pyramid.

Formvar negative replica. Shadowcast, chromium. (× 42,000)

Figure 12 has a complicated step structure where again one gets the definite impression of other steps just below the limit of resolution of the instrument. All these fairly complete crystal forms are transparent to light; the ones with irregular terraces diffuse the light quite thoroughly.

In Fig. 13 is a Mayan temple with recessed trihedral corner detail which seems to give some insight into the nature of the structure. Figure 14 illustrates a complex arrangement of pyramids and steps.

Figure 15 has various items of a nature which has been discussed already, but in addition shows an interesting prism formation which apparently is a possible crystal growth habit of this material. Figure 16 seems to show that the ends of these prisms can have the terraced form.

An indication appears in Fig. 17 that under some circumstances barium titanate tends to crystallize in the form of rhombuses.

The limit of resolution of our instruments is probably not better than 50 angstroms, and in inspecting the pictures which are shown, if one bears this in mind as well as the fact that the replicas were shadowcast, an estimate of the total depth of the layer structures comes to several hundred angstroms. The thickness of the films used probably runs in the vicinity of 1,000 angstroms.

SUMMARY

The grains in the ceramic plates are found to crystallize in the form of uncompleted terraces. The successive layers have evidently begun to form each in the interior of the previous layer, in contradiction of the theories of Kossel and Stranski but in accordance with the Frank-Read mechanism of double screw dislocations.

In the ceramic ribbon some grains act as acquisitive centers, growing into more perfect forms which will transmit light, with the evidence still apparent

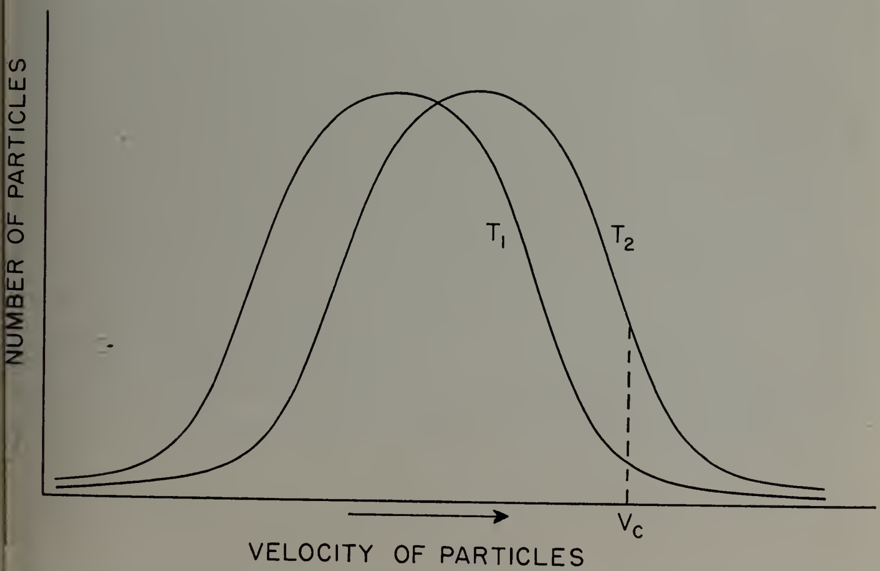

FIGURE 10—Velocity distribution curves for the filching process, showing how the cooler grain acquires the energy needed to build layers which are more nearly complete.

FIGURE 11—Ribbon surface. A stepped structure plus two complete pyramids. There is evidence here that complete laminated pyramids constitute a form of growth of barium titanate crystals. More steps are evident, close to resolution limit. Formvar negative replica. Shadowcast, chromium. (× 42,000)

FIGURE 12—Ribbon surface. A complicated step structure. Many more steps just beyond the limit of resolution are suggested.

Formvar negative replica. Shadowcast, chromium. (× 36,000)

Figure 13—Thin ribbon. Partial pyramid with recessed trihedral corner. Formvar negative replica. Shadowcast, chromium. (× 53,000)

that the layers grow from the interior out toward the edges and corners. Several geometric forms of growth are found.

ACKNOWLEDGMENT

The authors acknowledge the valuable technical aid given them in this investigation by Gustave A. Larson, David W. MacLeod, and John L. Sampson, and consider themselves particularly fortunate to have had the benefit of the photographic skill of Professor Carl A. Stevens.

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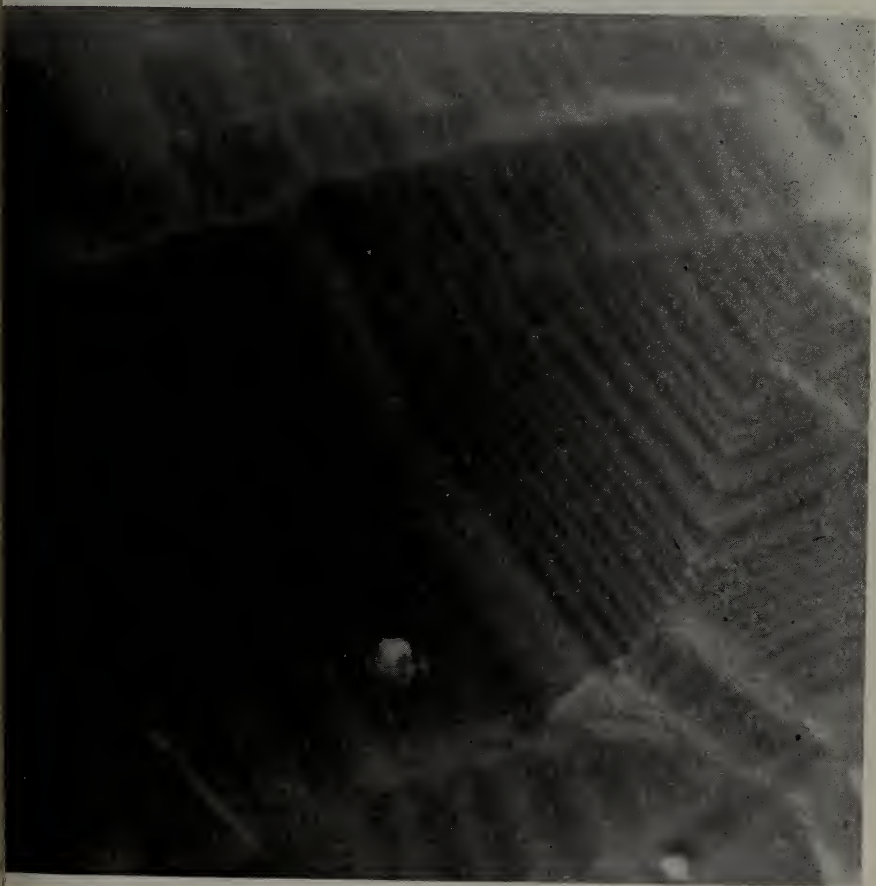

GURE 14—Barium titanate ribbon surface. A complex arrangement of pyramids and steps.

Formvar negative replica. Shadowcast, chromium. (× 40,000)

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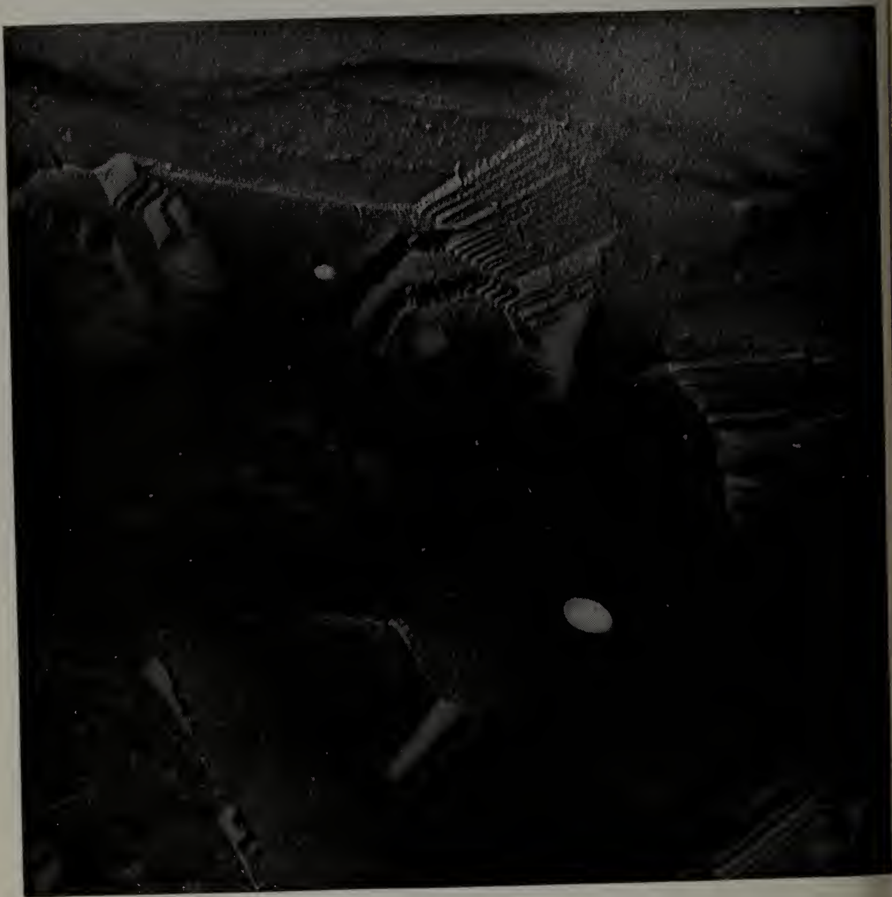

FIGURE 15—Ribbon surface. Perhaps the most interesting feature shown here is the prism formation at the right-hand side of the picture.
Formvar negative replica. Shadowcast, chromium. (× 15,000)

FIGURE 16—Ribbon surface. This terraced cap seems to be at the end of a prism formation.

Formvar negative replica. Shadowcast, chromium. (× 22,000)

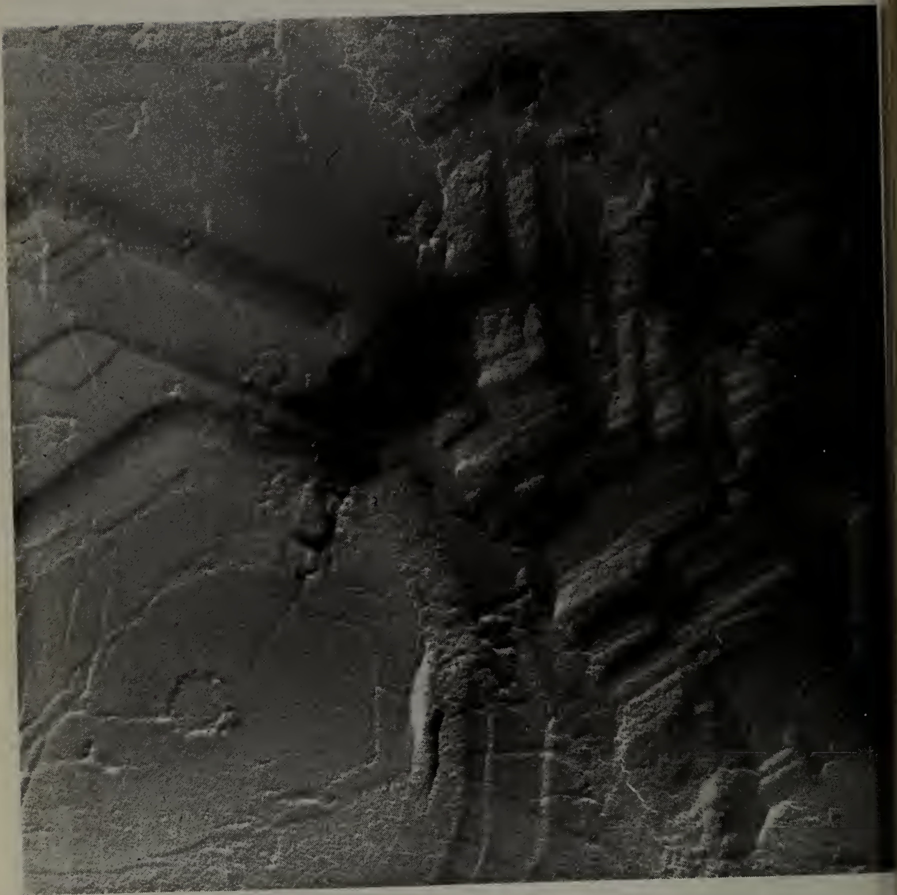

FIGURE 17—Barium titanate ribbon surface. Note the clearly defined tendency here to crystallize in rhombus forms.

Formvar negative replica. Shadowcast, chromium. (× 27,000)

SERIES 61. NO. 4.
CURRICULUM BULLETIN

BULLETIN

of the

Lowell Technological Institute of Massachusetts

LOWELL, MASS.

1958-1959

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Textile and Colonial Avenue

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CALENDAR — 1958-1959

First Semester

September 8, 9, 16, 1958, 7-8:30 P.M.	Registration
September 22, 1958, Monday	Classes begin
October 13, 1958, Monday	Columbus Day, holiday
November 11, 1958, Tuesday	Veterans' Day, holiday
November 26, 27, 28, 1958, Wednesday, Thursday and Friday	Thanksgiving recess
December 22, 1958, Monday	Christmas recess begins
January 5, 1959, Monday	Classes resume
January 16, 1959, Friday	End of first semester

Second Semester

January 13, 14, 15, 1959, 7-8:30 P.M.	Registration
January 26, 1959, Monday	Classes begin
February 23, 1959, Monday	Washington's Birthday, holiday
March 27, 1959, Friday	Easter recess begins
April 6, 1959, Monday	Classes resume
April 20, 1959, Monday	Patriots' Day, holiday
May 15, 1959, Friday	End of second semester

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GENERAL INFORMATION

Registration

Students may register by filling out the necessary forms and paying fees before attending classes. Registration is held on the dates indicated in the calendar.

Classes are held on Monday, Tuesday, Wednesday, Thursday, and Friday evenings each week, usually from 7:00 P.M. to 9:00 P.M., although other hours are sometimes required in particular subjects. Classes for those students taking courses toward an Associate Degree will be held from 7:00 P.M. to 9:30 P.M.

The scheduled nights for the various subjects in the following pages are tentative and may be altered in a few cases.

A student must have reached his sixteenth birthday before registering in the Evening Division, unless he has special permission from the Director of the Evening Division.

Late Registration

No new registrations or class changes will be accepted after the first two weeks of classes have been held.

Registration Fee

A registration fee of one dollar per semester is required of all students, in addition to tuition and other charges.

Tuition

Tuition charges for Associate Degree courses will be found on page 8; for Certificate courses, on page 26.

Employees of Lowell Technological Institute

Employees of the Lowell Technological Institute and its Research Foundation are exempt from all tuition charges.

All tuition and fees must be paid in full at the time of registration.

Laboratory Fees

Students electing any subject that requires laboratory work must pay a laboratory fee of $20 per semester in addition to their tuition. These fees are to cover supplies and normal breakage. Any excessive breakage will be billed directly to the student and must be paid before credit can be obtained. No portion of these laboratory fees will be returned except as provided in the section on refunds. These laboratory fee requirements apply to all students whether they are residents or nonresidents of Lowell and whether they are studying for credit or noncredit.

Refunds

Students dropping out of a class before the end of the first two weeks may obtain a refund of 80% of their tuition and fees. Students dropping out of a class from the second to the fifth week may be refunded 50% of their tuition and fees. There are no refunds after the fifth week of classes. A student must file an application for refund before one can be made. The registration fee of one dollar will not be returned in any case unless the class is cancelled.

Size of Class

No first-year subject will be given unless at least 15 students register for it. In a few instances, more than that number are required. Advanced subjects will usually, but not necessarily, be given regardless of number.

Veterans

All veterans entitled to educational benefits under the law should secure from the V. A. Office a certificate of eligibility before registering.

Books and Supplies

Students must provide their own books, paper, and drawing materials, and pay for any breakage or damage of school equipment that they may cause.

Student supplies will be sold by the school cooperative store each school evening from 6:45 P.M. to 8:15 P.M.

Credits

Subjects considered of college level are indicated in the subject descriptions, and credit hours are assigned to them. A high-school diploma is a prerequisite for all college-level courses.

Transfer Credit

No credit shall be allowed for work done elsewhere which has not been passed with a grade the equivalent of a C (70-79).

No grade for work successfully completed at other institutions shall be considered in computing a student's cumulative rating. Transfer subjects shall be merely recorded with the notation "Cr." When a student requires a record of grades for work done elsewhere, he must obtain an official transcript from the college in question.

Grading System

The following system of grading is used:

A	90 - 100	Excellent
B	80 - 89	Good
C	70 - 79	Fair
D	60 - 69	Lowest Passing Grade
F	50 - 59	Failure
W	Withdrawn	
X	Dropped	

The student's semester rating is a weighted value used to denote his relative standing. The point values assigned are: A = 4 points, B = 3 points, C = 2 points, D = 1 point, and F = 0 points. These point values, when multiplied by the credit hours assigned to the subject and added together, are divided by the sum of the credit hours to give the student's semester rating. The cumulative rating of more than one semester will be obtained in the same manner as the computation for the rating of a single semester.

Please note that no student will be permitted to graduate from the Associate Degree courses with less than a 1.5 cumulative rating.

Information

Address correspondence to Director of Evening Division, Lowell Technological Institute, Lowell, Massachusetts.

ASSOCIATE DEGREE

PROGRAMS OF STUDY

Entrance Requirements

For subjects taken toward an Associate Degree in Engineering the requirement is graduation from a recognized high school or equivalent study or achievement, including one year of algebra.

Conditioned Students

Applicants for the Associate Degree in Engineering who do not meet the full requirements for admission as regular students may, at the discretion of the Committee on Admissions, be admitted as conditioned students provided the secondary-school work completed embraces one unit of algebra.

A conditioned student whose scholarship is satisfactory but who has not removed his conditions within the time specified by the Committee on Admissions may be permitted to continue with his program of studies. However, on the completion of the chosen four-year curriculum he will receive a diploma rather than the Degree of Associate in Engineering.

Students who wish to register for single subjects in the engineering curriculum can do so provided they have the necessary prerequisites.

Tuition

Tuition is at the rate of $10 per credit hour.

Attendance

Students must attend 80% of all classes. Four unexplained absences in a row will result in the student's being automatically dropped from the rolls.

ASSOCIATE DEGREE

First Semester Subjects (Sept.-Jan.)

7-9:30 p.m.

NUMBER	SUBJECT	EVENINGS	ROOM	PREREQUISITE
C-1	General Chemistry	Monday	P-309	None
C-1L	General Chemistry Lab.	Wednesday	S-305	C-1 concurrently
C-3	Qualitative Analysis	Tuesday	P-305	C-2
C-3L	Qualitative Analysis Lab.	Thursday	S-305	C-3 concurrently
C-5	Organic Chemistry	Monday	P-207	C-2
C-5L	Organic Chemistry Lab.	Wednesday	P-207	C-5 concurrently
C-7	Physical Chemistry	Not offered 1958-59		C-4
C-7L	Physical Chemistry Lab.	Not offered 1958-59		C-7 concurrently
C-9	Organic High Polymer Chemistry	Not offered 1958-59		C-8
C-11	High Polymer Lab.	Not offered 1958-59		C-10
C-15	General Colloid Chemistry	Not offered 1958-59		C-6
E-1	A.C. Machinery Lab. II	Monday	K-105	E-6
E-3	Advanced Electronic Lab. I	Tuesday or Thursday	S-225	E-115 concurrently
E-5	Algebra	To be arranged		E-7 or high-school algebra
E-11	Analytical Geometry & Differential Calculus	Tuesday or Thursday	PL-231	E-114
E-15	Applied Leather Analysis	Not offered 1958-59		C-6
E-19	Applied Mechanics	Tuesday or Thursday	P-215	E-114, E-90
E-29	D.C. Machinery	Tuesday	PL-330	E-10
E-31	D.C. Machinery Lab.	Thursday		E-29 concurrently
E-33	D.C. Theory	Monday or Wednesday	S-209	E-114, E-90
E-37	Electronics for Industry	Thursday	F-305	E-114, E-6
E-39	Electronic Physics	Monday or Wednesday	P-301	E-90
E-41	Electron Tubes	Tuesday	S-318	E-10
E-41A	Circuits I	Thursday	S-318	E-41 concurrently
E-43	Electrical Measurements	Monday or Wednesday	S-318	E-52, E-10
E-45	Engineering Drawing	To be arranged		None
E-53	Heat Engineering	Wednesday	P-309	E-90
E-55	Job Evaluation and Merit Rating	Thursday	K-201	None
E-57	Leather Technology	Not offered 1958-59		C-6
E-59	Leather Technology	Not offered 1958-59		E-56
E-67	Machine Design	Wednesday	P-403	E-108
E-69	Machine Drawing	Monday	K-311	E-38
E-79	Mechanical Engineering Lab.	Tuesday	K-105	E-46
E-81	Mechanism	Thursday	P-217	E-68
E-87	Paper Technology	Not offered 1958-59		C-6
E-89	Paper Technology	Not offered 1958-59		E-84
E-91	Paper Manufacturing—Testing and Analysis	Not offered 1958-59		C-6
E-93	Paper Manufacturing—Testing and Analysis	Not offered 1958-59		E-80
E-95	Physical Testing of Leather	Not offered 1958-59		E-54
E-99	Physics	To be arranged		None
E-103	Plastic Technology	Not offered 1958-59		C-6
E-105	Plastic Technology	Not offered 1958-59		E-92
E-115	Communication Engineering	Monday & Wednesday	F-313	E-36
E-117	Rubber Technology	Not offered 1958-59		C-6
E-119	Rubber Technology	Not offered 1958-59		E-102
E-123	Strength of Materials	Monday	P-215	E-18, E-52
E-127	Time Study	Wednesday	P-215	None
E-131	Properties of Polymers	Not offered 1958-59		C-10

ASSOCIATE DEGREE

Second Semester Subjects (Jan.-May)

7-9:30 p.m.

NUMBER	SUBJECT	EVENINGS	ROOM	PREREQUISITE
C-2	General Chemistry	Monday	P-309	C-1
C-2L	General Chemistry Lab.	Wednesday	S-305	C-2 concurrently
C-4	Quantitative Analysis	Monday	P-305	C-2
C-4L	Quantitative Analysis Lab.	Wednesday	P-305	C-4 concurrently
C-6	Organic Chemistry	Monday	P-207	C-5
C-6L	Organic Chemistry Lab.	Wednesday	P-207	C-6 concurrently
C-8	Physical Chemistry	Not offered 1958-59		C-7
C-8L	Physical Chemistry Lab.	Not offered 1958-59		C-8 concurrently
C-10	Physical Chemistry of High Polymers	Not offered 1958-59		C-9
C-12	High Polymer Lab.	Not offered 1958-59		C-11
C-16	General Colloid Chemistry	Not offered 1958-59		C-15
E-2	Advanced Electronic Lab. II	Tuesday or Thursday	S-225	E-40, E-48 concurrently
E-6	A.C. Machinery	Tuesday	PL-330	E-29
E-8	A.C. Machinery Lab.	Thursday	PL-330	E-6 concurrently
E-10	A.C. Theory	Monday or Wednesday	S-209	E-33
E-18	Applied Mechanics	Tuesday or Thursday	P-215	E-19
E-32	Electronics for Industry Lab.	To be arranged		E-37
E-34	Electronic Lab.	Monday or Wednesday	S-225	E-36, E-36A concurrently
E-36	Electron Tubes	Tuesday	S-318	E-41
E-36A	Circuits II	Thursday	S-318	E-36 concurrently
E-38	Engineering Drawing	To be arranged		E-45
E-40	Frequency Modulation	Monday	F-313	E-115
E-40A	Television	Wednesday	F-313	E-40 concurrently
E-46	Heat Engineering	Wednesday	P-309	E-53
E-48	Hydraulics	Thursday	P-217	E-18
E-52	Integral Calculus	Tuesday or Thursday	PL-231	E-11
E-54	Leather Histology	Not offered 1958-59		E-15
E-56	Leather Technology	Not offered 1958-59		E-57
E-58	Leather Technology	Not offered 1958-59		E-59
E-66	Machine Design	Tuesday	P-403	E-67
E-68	Machine Drawing	Monday	K-311	E-69
E-78	Machine Shop Practice	Wednesday	K-104	E-79
E-80	Paper Manufacturing—Testing and Analysis	Not offered 1958-59		E-91
E-82	Paper Manufacturing—Testing and Analysis	Not offered 1958-59		E-93
E-84	Paper Technology	Not offered 1958-59		E-87
E-90	Physics	To be arranged		E-99
E-92	Plastic Technology	Not offered 1958-59		E-103
E-94	Plastic Technology	Not offered 1958-59		E-105
E-96	Principles of Production and Planning	Wednesday	PL-330	None
E-100	Research Problems in Leather	Not offered 1958-59		E-95
E-102	Rubber Technology	Not offered 1958-59		E-117
E-104	Rubber Technology	Not offered 1958-59		E-119
E-106	Semiconductors and Transistors	Not offered 1958-59		E-10, E-39
E-108	Strength of Materials	Monday	P-215	E-123
E-112	Transmission and Distribution Theory	Tuesday	P-217	E-6
E-114	Trigonometry	To be arranged		E-5
E-118	Work Simplification	Thursday	PL-320	None
E-132	Properties of Polymers	Not offered 1958-59		E-131

CHEMISTRY

LEADING TO THE DEGREE OF ASSOCIATE IN SCIENCE

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics I	2½	E-90	Physics II	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chem. Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
C-7L	Physical Chemistry Lab.	2½	C-8L	Physical Chemistry Lab.	2½
	Elective	2½		Elective	2½
		7½			7½

ELECTRICAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
E-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
E-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
E-33	D.C. Theory	2½	E-10	A.C. Theory	2½
E-19	Applied Mechanics I	2½	E-18	Applied Mechanics II	2½
		7½			7½

THIRD YEAR

E-123	Strength of Materials	2½	E-108	Strength of Materials	2½
E-29	D.C. Machinery	2½	E-6	A.C. Machinery	2½
E-31	D.C. Machinery Lab.	2½	E-8	A.C. Machinery Lab. I	2½
		7½			7½

FOURTH YEAR

E-37	Electronics for Industry	2½	E-112	Transmission Theory	2½
E-53	Heat Engineering	2½	E-46	Heat Engineering	2½
E-1	A.C. Machinery Lab. II	2½	E-32	Electronics for Industry Lab.	2½
		7½			7½

ELECTRONIC ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
E-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
E-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
E-33	D.C. Theory	2½	E-10	A.C. Theory	2½
E-39	Electronic Physics	2½	E-43	Electrical Measurements	2½
		7½			7½

THIRD YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-41	Electron Tubes	2½	E-36	Electron Tubes	2½
E-41A	Circuits I	2½	E-36A	Circuits II	2½
E-43	Electrical Measurements	2½	E-34	Electronic Lab.	2½
		7½			7½

FOURTH YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-115	Communication Engineering	5	E-40	Frequency Modulation	2½
E-3	Advanced Electronic Lab. I	2½	E-40A	Television	2½
			E-2	Advanced Electronic Lab. II	2½
		7½			7½

Semiconductors and Transistors (E-106) will not be given in 1958-59. Beginning in 1959-60 this subject will be given in the first semester of the third year of the Electronic Engineering course instead of the second semester of the second year. Electrical Measurements (E-43) will be given in the second semester of the second year instead of the first semester of the third year.

INDUSTRIAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester

Course No.	COURSE	Class Hours
E-5	Algebra	2½
E-45	Engineering Drawing	2½
E-99	Physics I	2½
		7½

Second Semester

Course No.	COURSE	Class Hours
E-114	Trigonometry	2½
E-38	Engineering Drawing	2½
E-90	Physics II	2½
		7½

SECOND YEAR

Course No.	COURSE	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½
E-19	Applied Mechanics	2½
E-69	Machine Drawing	2½
		7½

Course No.	COURSE	Class Hours
E-52	Integral Calculus	2½
E-18	Applied Mechanics	2½
E-68	Machine Drawing	2½
		7½

THIRD YEAR

Course No.	COURSE	Class Hours
E-123	Strength of Materials	2½
E-55	Job Evaluation and Merit Rating	2½
E-53	Heat Engineering	2½
		7½

Course No.	COURSE	Class Hours
E-108	Strength of Materials	2½
E-118	Work Simplification	2½
E-46	Heat Engineering	2½
		7½

FOURTH YEAR

Course No.	COURSE	Class Hours
E-67	Machine Design	2½
E-127	Time Study	2½
	Engineering Elective	2½
		7½

Course No.	COURSE	Class Hours
E-66	Machine Design	2½
E-96	Principles of Production Planning	2½
	Engineering Elective	2½
		7½

LEATHER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	Course	Class Hours	Second Semester Course No.	Course	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-99	Physics	2½	E-99	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
E-15	Applied Leather Analysis	2½	E-54	Leather Histology	2½
E-57	Leather Technology	2½	E-56	Leather Technology	2½
		7½			7½

FIFTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-59	Leather Technology	2½	E-58	Leather Technology	2½
E-95	Physical Testing of Leather	2½	E-100	Research Problems in Leather	2½
		5			5

MECHANICAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
E-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
E-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
E-19	Applied Mechanics	2½	E-18	Applied Mechanics	2½
E-69	Machine Drawing	2½	E-68	Machine Drawing	2½
		7½			7½

THIRD YEAR

E-123	Strength of Materials	2½	E-108	Strength of Materials	2½
E-81	Mechanism	2½	E-48	Hydraulics	2½
E-53	Heat Engineering	2½	E-46	Heat Engineering	2½
		7½			7½

FOURTH YEAR

E-67	Machine Design	2½	E-66	Machine Design	2½
E-79	Mechanical Engineering Lab.	2½	E-78	Machine Shop Practice	2½
	Engineering Elective	2½		Engineering Elective	2½
		7½			7½

PAPER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics	2½	E-90	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
E-87	Paper Technology	2½	E-84	Paper Technology	2½
E-91	Paper Manufacturing—Testing and Analysis	2½	E-80	Paper Manufacturing—Testing and Analysis	2½
		7½			7½

FIFTH YEAR

E-89	Paper Technology	2½	E-86	Paper Technology	2½
E-93	Paper Manufacturing—Testing and Analysis	2½	E-82	Paper Manufacturing—Testing and Analysis	2½
C-15	General Colloid Chemistry	2½	C-16	General Colloid Chemistry	2½
		7½			7½

PLASTICS ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics	2½	E-90	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
C-9	Organic High Polymer Chemistry	2½	C-10	Physical Chemistry of High Polymers	2½
E-103	Plastic Technology	2½	E-92	Plastic Technology	2½
		7½			7½

FIFTH YEAR

C-11	High Polymer Lab.	2½	C-12	High Polymer Lab.	2½
E-105	Plastic Technology	2½	E-94	Plastic Technology	2½
E-131	Properties of Polymers	2½	E-132	Properties of Polymers	2½
		7½			7½

RUBBER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-99	Physics	2½	E-90	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
C-9	Organic High Polymer Chemistry	2½	C-10	Physical Chemistry of High Polymers	2½
E-117	Rubber Technology	2½	E-102	Rubber Technology	2½
		7½			7½

FIFTH YEAR

Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
C-11	High Polymer Lab.	2½	C-12	High Polymer Lab.	2½
E-119	Rubber Technology	2½	E-104	Rubber Technology	2½
		5			5

ASSOCIATE DEGREE

COURSE DESCRIPTIONS

C-1, C-1L; and C-2, C-2L General Chemistry. Two semesters of basic inorganic chemistry for those with no previous knowledge of chemistry. The fundamental laws of chemistry; the preparation, properties and uses of metals, nonmetals and related compounds; the simple chemical calculations. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 10 credits.

C-3 and C-3L Qualitative Analysis. The systematic analysis of inorganic compounds, carried out by the student in the laboratory using semi-micro technique. Chemical calculations and the balancing of chemical equations are covered in the stoichiometry portion of the course. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 5 credit hours.

C-4 and C-4L Quantitative Analysis. One semester of quantitative analysis for those not desiring college credit in chemistry but who wish to develop laboratory skills and techniques of a practical nature. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 5 credits.

C-5, C-5L; and C-6, C-6L Organic Chemistry. A study of the important classes of carbon compounds and the fundamental theories of organic chemistry. Lecture, 7—9:30 P.M.; laboratory, 7—9:30 P.M. 10 credits.

C-7, C-7L; and C-8, C-8L Physical Chemistry. This subject is designed for those in the laboratory or industry. It includes a discussion of properties of gases, liquids, solids, and solutions; chemical equilibrium, phase equilibrium, thermochemistry, electrochemistry, and other topics according to the need of the students. Laboratory work is assigned as required to give the student practice in the methods and apparatus of physical chemistry. Laboratory work includes the measurement of vapor pressure, viscosity, surface tension, heat of combustion and reaction, conductivity, determination of molecular weight, pH by various methods, etc. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 10 credits.

C-9 and C-10 High-Polymer Chemistry. The chemical structure of high polymers and their manufacture and preparation. The chemical reactions of plastics and their physical properties in relation to their chemical structure. This subject is designed for those in the plastics industry who desire to keep abreast of modern theory or broaden their background. Lecture, 7—9:30 P.M. 5 credits.

C-11 and C-12 See E-92, E-94, E-103, E-105.

C-15 and C-16 General Colloid Chemistry. The basic general principles of colloidal chemistry, followed by elementary analyses of important problems encountered in amorphous materials such as paints, cellulosic products, leather, paper, and textiles. Lecture, 7—9:30 P.M. 5 credits.

E-1 Alternating-Current Machinery Laboratory II. Tests on the single-phase and three-phase induction motors, the brush-shifting motor, investigation of induction motor windings, and tests on the Amplidyne generator. 2½ credits.

E-2 Advanced Electronics Laboratory II. Frequency and phase modulation and demodulation circuits. Video amplifiers, television pulse generators, multivibrators and counters. 2½ credits.

E-3 Advanced Electronics Laboratory I. Audio frequency amplifiers, intermediate frequency amplifiers, mixers, phase inserters, self-excited oscillators,

frequency multipliers. Testing and alignment of complete receivers. Class C radio frequency amplifiers and amplitude modulation methods. 2½ credits.

E-5 Algebra. Fractions, linear and quadratic equations, functions and graphs, systems of equations, determinants, exponents, variation, binomial theorem, theory of equations, and complex numbers. 2½ credits.

E-6 Alternating-Current Machinery. Alternating-current generation, alternator regulation, parallel operation, single-phase and three-phase transformers, vector diagrams, losses and efficiency, polyphase induction motors, torque and speed, power factor, methods of starting, synchronous motors, effect of field excitation and load, power factor correction, single-phase motors, methods of starting, testing of a.c. generators and motors. 2½ credits.

E-8 Alternating-Current Machinery Laboratory I. Measurements of current and voltage in single phase a.c. circuits containing resistance and reactance, power measurement in three-phase circuits, transformer efficiency and regulation, constant-current transformer, efficiency and regulation of alternators, synchronous motors, single-phase motors, characteristics of three-phase induction motors, circle diagram, speed-torque curves, speed control by means of a Thyratron. 2½ credits.

E-10 Alternating Currents. Principles of alternating currents and voltages, impedance, reactance, vector representation, instantaneous and average power, series and parallel circuits, resonance, three-phase circuits, delta and wye-connections, three-phase power. 2½ credits.

E-11 and E-13 Analytic Geometry & Differential Calculus. Straight line; conic sections; differentiation of algebraic, trigonometric, logarithmic, and exponential functions; differentials; rates; slopes of curves; maxima and minima. 5 credit hours.

E-15 Applied Leather Analysis. A subject designed to acquaint the student with the accepted methods of analysis of the American Leather Chemists Association and other supplementary procedures. 2½ credits.

E-18 and E-19 Applied Mechanics. The fundamentals of statics, including such topics as force systems, laws of equilibrium, friction, centers of gravity, moments of inertia, stress fundamentals, strain, bending moment and deflection. 5 credits.

E-29 Direct-Current Machinery. Generator principles, armature and field windings, types of generators, armature reaction, compensation, characteristics of shunt and compound generators, amplidyne, motor principles, shunt motor, series motor, compound motor, motor controllers and starters, motor testing, applications of d.c. generators and motors. 2½ credits.

E-31 Direct-Current Machinery Laboratory. Direct-current generator connections, compound generators, parallel operation of generators, efficiency measurements, starting rheostats for d.c. motors, shunt-motor characteristics, series motors, compound motors, efficiency of d.c. motors, determination of stray power losses, operation of balancer set, dynamotor. 2½ credits.

E-32 Electronics for Industry Laboratory. Characteristics of high-vacuum triodes, thyratron characteristics, grid-control methods, control by phase shifting, resistance-welding controls, synchronous timing, thyratron photoelectric relay, heating and lighting controls, speed and voltage regulators for d.c. motors and generators, polyphase rectifiers, saturable reactors, ignition rectifier. 2½ credits.

E-33 Direct Currents. Units of current, resistance and voltage, resistance of wires, temperature coefficient, series circuits, parallel circuits, Ohm's law and

Kirchoff's law, energy and power, Thevenin's theorem, magnetic fields and lines of force, magnetic fields produced by electric currents, electromagnets, d.c. ammeters and voltmeters, the electric field, properties of dielectrics. 2½ credits.

E-34 Electronic Laboratory. Electron dynamics, thermionic emission, characteristics of vacuum and gas diodes, triodes. Equivalent circuits for tubes, voltage and power amplifiers. Photo-cells, cathode ray oscilloscopes, impedance bridge and vacuum tube voltmeters. (Must be taken concurrently with E-36.) 2½ credits.

E-36 and E-36A Electron Tubes and Circuits II. Vacuum tube amplifiers of all classes; distortion; coupling methods; inverse feedback in amplifiers. 5 credits.

E-37 Electronics for Industry. Single and polyphase rectification and filtering. Basic electron tubes; voltage and current stabilization circuits; thyratron and photo-tube control circuits and applications. 2½ credits.

E-38 and E-45 Engineering Drawing. Freehand and mechanical drawing, including lettering, geometric construction, orthographic projection, isometric and cabinet drawing, and dimensions, auxiliary views, cross sections, advanced dimensioning, sketching of machine parts, working drawings, tracing and blueprinting, intersections, and developments. 5 credits.

E-39 Electronic Physics. Introductory field theory applied to propagation in free space, dielectrics, and conductors. Reflection and refraction of waves; interference, diffraction, and polarization. Transmission lines; antennas; impedance matching. Properties of the ionosphere. 2½ credits.

E-40 and E-40A Frequency Modulation and Television. Principles of conveying electronic visual information by wire, radio photo, facsimile, and television. Television systems: generation transmission and reception of television signals. 5 credits.

E-41 and E-41A Electron Tubes and Circuits I. Electron dynamics, thermionic emission, secondary emission, field emission, and photo-electric emission. Mechanical design consideration of radio tubes. Tube characteristics and coefficients. The application of radio tubes to amplifier circuits and rectifiers. 5 credits.

E-43 Electrical Measurements. Measurements of resistance, capacitance, inductance, impedance, voltage, current, and power. D.c. and a.c. bridge circuits, magnetic measurements, frequency and phase measurements. 2½ credits.

E-46 and E-53 Heat Engineering. The basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A brief treatment of steam engines, turbines and pumps. Special consideration is given to the use of steam in manufacturing processes. 5 credits.

E-48 Hydraulics. Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs; orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids, Mach's number; dynamical similitude and Pi theorem. 2½ credits.

E-52 Integral Calculus. Indefinite and definite integrals; areas; length of curves; area of surface of revolution; volumes of solids of revolution; integration of trigonometric, logarithmic, and exponential functions; methods of integration. 2½ credits.

E-54 Leather Histology. A study of the structures of animal skin and of the changes which they undergo in the leathermaking process. Because the basically extracellular nature of skin demands it, considerable time is devoted to the nature and function of the fundamental protein constituents. 2½ credits.

E-55 Job Evaluation and Merit Rating. Covers the principles and practices in the analysis of the job and the worker's performance on that job. Specific subjects covered include job description, determining job factors and translating these into rating values, wage calculations and wage structures. 2½ credits.

E-56, E-57, E-58, E-59 Leather Technology. Introduction to the technology of leather manufacture. The first two semesters are devoted to examining government regulations in imported hides and skins, studying the purchasing of hides and skins, and classifying various hide damages. This is followed by work on the handling of raw stock at the tannery, unhairing, bating, and hide classification. The third and fourth semesters are concerned primarily with the study of vegetable tanning, chrome tanning, and various other types of tanning. In the work throughout the year the material covered in lectures is supplemented by laboratory studies on a small scale. 10 credits.

E-66 and E-67 Machine Design. The design of machine elements, such as fasteners, shafts, frames, bearings, gears, clutches, springs, keys and drives. Data for most of the problems are taken from actual machines in the various laboratories. 5 credits.

E-68 and E-69 Machine Drawing. Several short problems involving centers of gravity, counterweights, cam layouts, piping, welding, sheet metal drafting, and assembly drawings. 5 credits.

E-78 *See* E-63, p. 29. 2½ credits.

E-79 Mechanical Engineering Laboratory. Fundamentals of engineering measurements, flow measurement of steam and air, tests of steam turbine and internal-combustion engine, experimental work with refrigeration units, measurements of heat transfer, combustion, fluid flow, performance of pumps, and testing of engineering material. 2½ credits.

E-80, E-82, E-91, E-93 Paper Manufacturing — Testing and Analysis. An elementary study of the fundamental processing techniques used in paper manufacture. The lecture work is accompanied by laboratory training in papermaking, paper testing and analysis, and paper microscopy. 10 credits.

E-81 Mechanism. The basic principles of kinematics, in which the wide variety of process machinery available furnishes many specific examples. Frequent use of these mechanisms is made in the development of the subject. Some of the important topics covered are the following: rolling cylinders and cones, gearing, gear train design, epicyclic gear trains, flexible connectors including stepped pulley and cone design, cam design, linkages, and miscellaneous mechanisms. 2½ credits.

E-84, E-86, E-87, E-89 Paper Technology. Lectures on the production and technology of pulp and paper. 10 credits.

E-90 and E-99 Physics. The fundamentals of mechanics, heat, sound, electricity, and light. The first-semester topics include force systems, energy and power, motion, liquids and gases, calorimetry and thermodynamics. The second-semester topics include wave motion, sound phenomena, magnetism, electrostatics, d.c. and a.c. circuits, reflection and refraction of light, lenses, optical instruments, physical optics, and elements of atomic physics. 5 credits.

E-92 and E-103 Plastic Technology. This is an introductory study of plastics. It includes history, classification, properties, definitions, and uses. Raw materials, methods of manufacturing, processing, and fabrication. Lectures and laboratory. 5 credits.

E-94 and E-105 Plastic Technology. Additional instruction in processing and fabrication. Applications of plastics, engineering properties, equipment, mold and product design. Testing of plastics. Lectures and laboratory. 5 credits.

E-95 Physical Testing of Leather. A practical and theoretical study of the characteristics of leather in relation to the end use. Studies are made on measuring and classifying the effect of changes in manufacturing procedure, both chemical and physical. Leather, because it is a natural product, varies considerably within the same hide. Thus the nature of this variation is very important, and the study of any changes affecting it is, in turn, important. 2½ credits.

E-96 Principles of Production Planning. The student is introduced to the processes followed in planning from the original idea of the product to the shipment of the finished product from the plant. Among the topics covered are product analysis, plant location and layout, organization, budgeting, and control. 2½ credits.

E-100 Research Problems in Leather. This subject is designed primarily to enable the student to apply the various scientific principles of physics, chemistry, mathematics, economics, etc., to problems of an industrial nature. This may encompass anything from the design and layout of a special leather plant to the suggested solution of practical problems which arise in the operation of a modern business. 2½ credits.

E-102 and E-117 Fundamentals of Rubber Technology. An introductory course for those who wish to acquire a general knowledge of rubber technology. Physical properties, composition, compounding, vulcanization, evaluation, deterioration, etc., of various types of synthetic rubbers and natural rubber. Lectures and laboratory. 5 credits.

E-104 and E-119 Advanced Rubber Chemistry and Technology. Monomers; polymerization systems; relation of chemical structure to physical properties; theories of vulcanization, acceleration, reinforcement, and deterioration of elastomers. Lectures and demonstrations. 5 credits.

E-106 Semiconductors and Transistors. An introduction to solid state electronics. Crystal diodes transistors: their operation and applications. 2½ credits.

E-108 and E-123 Strength of Materials. This subject covers such topics as beams, beam design, torsion, columns, combined stresses, reversals of stress and impact. Includes such topics as bending and shearing stresses, torsion, compound beams and columns, reversals of stress, impact, vibrations, stress analysis by strain gage methods, concepts of creep and relaxation. 5 credits.

E-112 Transmission and Distribution of Power. Transmission systems, reactance, capacitance, three-phase line calculations, corona power, lightning arresters, transmission structures, transformer substations, distribution circuits, automatic substations. 2½ credits.

E-114 Trigonometry. Trigonometric functions, identities, reference angles, radians, multiple angles, trigonometric equations, logarithms, slide rule, right triangles, and oblique triangles. 2½ credits.

E-115 Communication Engineering. Theory and applications of thermionic tubes and transistors in amplifiers, oscillators, modulators, and detectors. Selectivity, sensitivity, stability of radio receivers and transmitters. 5 credits.

E-118 Work Simplification. The study of cost reduction through the analysis of the job, plant layout, tools and equipment, and of worker activity through the use of process, flow, operation, man and machine charts and the principles and practices of motion study. 2½ credits.

E-127 Time Study. The methods and rules of time study. A brief historical background is given before the student is introduced to the techniques of making time studies. Specific points covered include job standards, use of allowances, treatment of variables, use of data, "normal performance", and rating procedures. 2½ credits.

E-131 and E-132 Properties of Polymers. This subject includes the study of important engineering properties of plastics materials; theory of testing; the examination of testing techniques, equipment, and standard ASTM methods for evaluating mechanical, thermal, electrical, and optical properties. 5 credits.

CERTIFICATE COURSES

PROGRAM

Entrance Requirements

For subjects taken toward a certificate the requirement, in general, is graduation from grammar school or equivalent education.

Tuition for subjects not offering college credit or credit toward an Associate Degree is free to Lowell Technological Institute day students and residents of Lowell, but nonresidents will be charged as follows:

Evenings Per Week	*Hours Per Evening*	*Tuition*
1	2	$ 5.00
1	2½	6.25
1	3	7.50
2	2	10.00
2	2½	12.50
2	3	15.00
3	2	15.00
3	2½	18.75
3	3	22.50

All tuition and fees must be paid in full at the time of registration.

To receive free tuition, residents of Lowell must file a certificate of residence with the Registrar. These certificates may be obtained from the Election Commission, City Hall, Lowell. However, registration may be completed prior to filing the certificate.

Size of Class

No first-year subject will be given unless at least 15 students register for it. In a few instances, more than that number are required. Advanced subjects will usually, but not necessarily, be given regardless of number.

Attendance

Students must attend 70% of classes held in order to receive a certificate for the subject. Four unexplained absences in a row will result in the student's being automatically dropped from the rolls.

College Credit

A few of the certificate courses are given on the college level and carry college credit. They are so indicated on the course listings and subject descriptions. For these courses the tuition fees for college-credit courses, as shown on page 8, apply.

CERTIFICATE COURSES

First Semester Subjects (Sept.-Jan.)

7-9:00 p.m.

NUMBER	SUBJECT	EVENINGS	ROOM	PREREQUISITE
C-52	Organic Chemistry for the Medical and Biological Sciences (4 credits)	To be arranged		Permission of instructor
E-7	Algebra	Monday or Wednesday	PL-231	None
E-9	Algebra	Monday or Wednesday	K-201	E-7
E-17	Applied Mathematics	Monday and Wednesday	F-301	None
E-25	Blueprint Reading	Monday and Wednesday	F-307	None
E-49	Fundamentals of Plastics	Monday	P-203	None
E-61	Leather Technology	Tuesday and Thursday	PL-128	None
E-63	Machine Shop Practice	Monday or Wednesday	K-101	None
E-65	Machine Shop Practice	Thursday	K-101	E-63
E-71	Mechanical Drawing	Monday or Wednesday	K-305	None
E-73	Mechanical Drawing	Tuesday or Thursday	K-305	E-71
E-75	Mechanical Drawing	Tuesday or Thursday	K-311	E-73
E-77	Mechanical Drawing	Tuesday and Thursday	K-315	E-75
E-97	Physics	Monday or Wednesday	P-401	E-7 or high-school algebra
E-107	Pulp and Paper Technology	Tuesday	PL-201	None
E-109	Pulp and Paper Lab.	Wednesday	PL-201	E-107 concurrently
E-111	Statistical Quality Control	Monday and Thursday	P-403	None
E-121	Rubber Technology	Monday	PL-128	None
E-129	Trigonometry	Tuesday or Thursday	K-304	E-7 or high-school algebra
G-1	Accounting I	Monday and Wednesday	K-304	None
G-11	Cost Accounting	Monday	P-111	G-2
G-15	English Composition	Tuesday	F-301	None
G-23	Psychology	Monday	PL-201	None
G-25	Literature I (3 credits)	Monday	F-311	1 year college English
G-47	Vocabulary Building	Monday and Wednesday	F-305	None
G-49	Government Contracts	Tuesday and Thursday	P-203	None
MA-206	Differential Equations (3 credits)	Tuesday and Thursday	P-401	MA-202
MA-301	Advanced Calculus (3 credits)	Tuesday and Thursday	P-301	MA-202

COURSES IN TEXTILE MANUFACTURING ARE ALSO OFFERED. INFORMATION UPON REQUEST.

CERTIFICATE COURSES

Second Semester Subjects (Jan.-May)

7-9:00 p.m.

NUMBER	SUBJECT	EVENINGS	ROOM	PREREQUISITE
C-52A	Inorganic Chemistry for the Medical and Biological Sciences (4 credits)	To be arranged		Permission of instructor
E-4	Advanced Paper Technology	Tuesday	PL-201	E-107
E-7	Algebra	Monday or Wednesday	PL-231	None
E-9	Algebra	Monday or Wednesday	K-201	E-7
E-17A	Applied Mathematics	Monday and Wednesday	F-301	None
E-24	Blueprint Reading	Monday and Wednesday	F-307	None
E-60	Leather Technology	Tuesday and Thursday	PL-128	E-61
E-63	Machine Shop Practice	Monday or Tuesday	K-101	None
E-65	Machine Shop Practice	Thursday	K-101	E-63
E-71	Mechanical Drawing	Monday or Wednesday	K-305	None
E-73	Mechanical Drawing	Tuesday or Thursday	K-305	E-71
E-75	Mechanical Drawing	Tuesday or Thursday	K-311	E-73
E-77	Mechanical Drawing	Tuesday	K-315	E-75
E-97	Physics	Monday or Wednesday	P-401	E-7 or high-school algebra
E-111A	Advanced Quality Control	Thursday	P-403	E-111
E-129	Trigonometry	Tuesday or Thursday	K-304	E-7 or high-school algebra
G-2	Accounting II	Monday and Wednesday	K-304	G-1
G-8	Literature II (3 credits)	Monday	PL-330	1 year college English
G-16	English Composition	Tuesday	F-301	G-15
G-26	Meaning and Use of Words	Monday and Wednesday	F-305	None
G-49A	Government Contracts	Tuesday and Thursday	P-203	None
MA-206	Differential Equations (3 credits)	Tuesday and Thursday	P-401	MA-202
MA-302	Advanced Calculus (3 credits)	Tuesday and Thursday	P-301	MA-301

COURSES IN TEXTILE MANUFACTURING ARE ALSO OFFERED. INFORMATION UPON REQUEST.

CERTIFICATE COURSE DESCRIPTIONS

C-52A Inorganic Chemistry for the Medical and Biological Sciences. One semester of inorganic chemistry oriented for those working in the medical and biological sciences. The basic tenets of chemistry are surveyed in lecture and laboratory. Four hours of lecture and 2 hours of laboratory. 4 credits.

C-52 Organic Chemistry for the Medical and Biological Sciences. A one-semester survey course of the fundamentals of organic and biological chemistry. The aliphatics, aromatics, carbohydrates, fats, proteins, digestion, and metabolism are discussed. Two hours of lecture and 4 hours of laboratory. 4 credits.

E-4 Advanced Paper Technology. Details of manufacture of various papers and their conversion to a useful end product. Guest lecturers supplement the regular staff.

E-7 and E-14 Algebra. Algebra, including addition, multiplication, subtraction, division, factoring, and fractions.

E-9 and E-16 Algebra. A continuation of E-7 and E-14. Some of the topics treated are: graphical representation, linear equations, radicals, quadratic equations, logarithms, slide rule, and some trigonometry.

E-17 and E-17A Applied Mathematics. Designed for students who need a review of the fundamental processes and includes some plane and solid geometry, algebra, logarithms, and trigonometry. Use of the slide rule is stressed in the solution of practical problems.

E-24 Blueprint Reading. Similar to E-25, but with emphasis on architectural, rather than engineering, blueprints.

E-25 Blueprint Reading. The principles of mechanical drawing, *e.g.,* projections, sections, dimensioning, etc., necessary for the understanding of blueprints.

E-49 Fundamentals of Plastics. An introductory study for those who wish to acquire a general knowledge of plastics. Classification, description, chemical and physical properties, uses, and methods of fabrication.

E-60 and E-61 Leather Technology. The theoretical aspects of leather production coupled with a laboratory to carry out the planning of process control, material control, and product quality control. One section will be devoted to an intensive introduction to the histology of hides and skins and histological preparations.

E-63 and E-65 Machine Shop Practice. Metal-working, including bench work, lathes, grinders, planers, shapers, presses, milling machines, care of tools, tool grinding, heat treatment, forging and use of special tools. The classes are limited to 25 students.

E-71, E-73, E-75, E-77 Mechanical Drawing. Fundamentals of engineering drawing. The first semester covers lettering, use of instruments, geometric construction, orthographic projection, multi-view and pictorial freehand drawing. The second semester includes dimensioning, auxiliary views, cross-sectioning, screw threads and working drawings. The third semester offers intersections, pictorial drawings, and applications to sheet metal drawings. The fourth semester covers assembly drawings from details of parts and detailing from designers' assembly drawings.

E-97 Physics. Elementary physics on the high-school level. Lectures and demonstrations.

E-107 Pulp and Paper Technology. The basic principles of manufacture of the common papermaking pulps, followed by a study of stock preparation and paper machine operation.

E-109 Pulp and Paper Testing Laboratory. Laboratory work in the physical and chemical testing of pulps and papers.

E-111 Statistical Quality Control. This course starts off with instruction in the basic statistical concepts needed to understand and use the tools of quality control. It then proceeds to introduce and illustrate some of these "statistical tools." Subjects covered are: measures of central tendency and dispersion, normal curve analysis, simple process capability studies, basic control charts for measurable and nonmeasurable characteristics, acceptance sampling techniques and determination of tolerances. The emphasis is placed on the practical rather than the mathematical approach to quality problems. Case studies, audio-visual aids, and practical demonstrations are used to supplement the lectures.

E-111A Advanced Quality Control. This course will deal with some of the more advanced methods developed to aid in the solution of quality problems in industry. Techniques of process analysis and process control such as the Span Plan, modified control limits, Narrow Limit Gaging, and Pre-Control will be introduced and illustrated. Tests of significance such as: the X^2 test, the "t" test, the "F" test, and some nonparametric tests will be discussed. The course will also spend some time acquainting the student with some of the practical aspects of organization, administration, and economics of a quality control program.

E-121 Rubber Technology. An introductory course for those who wish to acquire a general knowledge of rubber technology.

E-129 Trigonometry. The solution of all triangles by both natural and logarithmic functions, identities, radian measure, principal values and the solution of trigonometric equations.

MA-206 Differential Equations. A review of series and partial differentiation, first- and second-order differential equations, and first- and second-order partial differential equations. Practical applications for the chemist and the engineer. 3 credits.

MA-301-302 Advanced Calculus. Ordinary differential equations, Laplace transformation, numerical methods of solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations, partial differential equations of mathematical physics, and complex variable theory. 6 credits.

G-1 and G-2 Accounting I and Accounting II. The principles of accounting. The first semester deals with the preparation and interpretation of reports and statements of financial position. The balance sheet, profit and loss statement, theory of debits and credits, ledger, etc., are covered. The second semester carries the student into payroll and tax accounting, partnership and corporate records, and the basic principles of cost accounting.

G-8 Literature II. This course aims to develop standards of literary criticism and to familiarize the student with six or more classics of western civilization. Lectures, class discussion, and critical papers form the basis of class meetings. College level; 3 credits.

G-11 Cost Accounting. An introduction to the study of the process of recording the expenses of operating a business from the standpoint of determining production and distribution costs.

G-15 English Composition. The basic elements of composition, including remedial English, grammar, sentence structure, etc.

G-16 English Composition. Writing for business and social purposes. Narration, description, reports, letters, etc.

G-23 Psychology. Basic techniques of press, radio, and television publicity with fundamental training in communications procedures, the social implications and professional responsibility of all media. Evaluation of promotional programs devised to create and ensure public awareness and goodwill.

G-25 Literature I. Attention is focused on six or seven major writers. Emphasis will be on discovering what these authors have to say that is of interest or importance to the general reader today. The student will have the opportunity to determine the attitude toward life of each writer, to see what gave rise to this attitude, and to evaluate it and compare it with the views of other writers considered in the course. College level; 3 credits.

G-26 The Meaning and Use of Words. The exact meaning of words and how their proper usage can lead to clear and dynamic speech.

G-47 Vocabulary Building. A subject to help the student enlarge his vocabulary and improve his understanding and choice of words. Language roots and word evolution are also studied.

LOWELL TECHNOLOGICAL INSTITUTE

Register of Courses

1958-1959

DIRECTORY

Further information concerning these subjects may be obtained by writing to the following sources:

admissions, scholarship aid	Dean of Students
official transcripts	Registrar
graduate studies	Director of Graduate School
summer school	Director of Summer School
evening study program	Director of the Evening Division
alumni affairs	Alumni Office
graduate placement	Placement Director
library industrial corporate membership	Librarian
conferences, special programs, public relations	Coordinator of Special Services
sponsored research	Lowell Technological Institute Research Foundation

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OFFICIAL CALENDAR

1958-59

September 8, Monday	Freshman Orientation Week begins.
	Registration of graduate students begins.
September 11, Thursday	Registration of seniors and juniors.
September 12, Friday	Registration of sophomores.
September 17, Wednesday	Classes begin.
September 30, Tuesday	Last day to register for new classes.
October 13, Monday	Columbus Day observance.
October 14, Tuesday	Last day to drop classes without penalty.
November 11, Tuesday	Veterans' Day.
November 26, Wednesday, 1 P.M.	Thanksgiving recess begins.
December 1, Monday	Classes resume.
December 19, Friday, 5 P.M.	Christmas recess begins.
January 5, Monday	Classes resume.
January 21, Wednesday	First-semester examinations begin.
January 30, Friday	First-semester examinations end.
February 2, Monday and February 3, Tuesday	Registration.
February 4, Wednesday	Classes begin.
February 17, Tuesday	Last day to register for new classes.
February 23, Monday	Washington's Birthday observance.
March 3, Tuesday	Last day to drop classes without penalty.
March 26, Thursday, 5 P.M.	Easter recess begins.
April 6, Monday	Classes resume.
April 20, Monday	Patriots' Day observance.
May 25, Monday	Second-semester examinations begin.
June 5, Friday	Second-semester examinations end.
June 14, Sunday	Baccalaureate and Commencement.

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ROLAND E. DERBY, JR., S.B., M.S., *Assistant Professor*
CHARLES A. EVERETT, B.T.C., *Assistant Professor*
VASILIS LAVRAKAS, B.S., M.S., *Assistant Professor*
WALTER J. LISIEN, B.T.C., *Assistant Professor*
EDWARD L. MCCAFFERY, B.S., M.S., Ph.D., *Assistant Professor*
ROBERT J. PEIRENT, B.S., M.S., *Assistant Professor*
JAMES B. PIERCE, B.S., M.S., Ph.D., *Assistant Professor*
RONALD M. PIKE, B.S., M.S., Ph.D., *Assistant Professor*
RAY E. MACAUSLAND, *Instructor*

Department of Plastics Engineering

RUSSELL W. EHLERS, B.S., M.A., Ph.D., *Professor, in charge of Department*
AUGUSTUS C. WALKER, JR., B.S., *Assistant Professor*
RAYMOND O. NORMANDIN, A.B., M.S., *Instructor*

DIVISION OF ENGINEERING

Charles R. Mingins, A.B., Ph.D., *Professor, Chairman of Division, and in charge of Department of Physics and Mathematics*

Department of Electronic Engineering

Carl A. Stevens, B.S., M.S., *Professor, in charge of Department*
Gerald Smithson, B.S., M.S., *Professor*
Robert L. Powell, B.A., M.A., *Associate Professor*
Leo A. Hart, B.S., *Instructor*
Joseph L. Poirier, B.S., *Instructor*
James E. Powers, B.S., *Instructor*
Earl F. Starr, Jr., B.S., *Instructor*

Department of Leather Engineering

Albert E. Chouinard, B.S., M.S., Ph.D., *Professor, in charge of Department*
Edward A. Botan, B.A., B.S., M.S., Ph.D., *Assistant Professor*
William E. Dooley, B.S., *Instructor*

Department of Nuclear Science and Engineering

Edward S. Gilfillan, Jr., B.S., Ph.D., *Professor and Acting Head of Department*
Raymond Gold, B.A., M.S., Ph.D., *Associate Professor*

Department of Paper Engineering

John Lewis, B.S., M.S., *Professor, in charge of Department*
Norwood H. Keeney, Jr., B.S., M.S., *Associate Professor*
Edward M. Engel, B.S., M.S., *Assistant Professor*
Charles J. Higgins, B.S., *Instructor*

Department of Physics and Mathematics

Charles R. Mingins, A.B., Ph.D., *Professor, in charge of Department*
Jonathan Karas, B.S., M.S., *Visiting Professor*
Andrew A. Ouellette, B.S., *Associate Professor*
Luther C. Barcus, B.A., M.S., *Assistant Professor*
Louis C. Block, B.S., Ed.M., *Assistant Professor*
Peter O. Cioffi, B.S., M.S., *Assistant Professor*
Robert K. Devejian, B.S., M.A., *Assistant Professor*
L. Ivan Epstein, B.S., M.S., *Assistant Professor*
Elwyn T. Hook, B.S., *Assistant Professor*
Thomas F. McElligott, A.B., Ed.M., *Assistant Professor*
Stephen J. Bodor, B.S., *Instructor*
Edward P. Champy, Jr., B.S., *Instructor*
James H. Doherty, Jr., B.A., *Instructor*
M. Brendan Fleming, B.S., M.A., *Instructor*
F. Raymond Hardy, B.S., *Instructor*
Robert C. Sanger, B.S., *Instructor*

Department of Textile Engineering

Henry E. Thomas, B.T.E., *Professor and Acting Head of Department*
Herbert J. Ball, S.B., B.C.S., Sc.D., *Fellow of the Textile Institute (British), Professor Emeritus*
Harry C. Brown, B.S., *Professor Emeritus*
Walter J. Hamburger, S.B., S.M., Ph.D., *Visiting Professor*
Melvin Mark, B.M.E., M.S., Sc.D., *Professor*
A. Edwin Wells, B.T.E., M.Ed., *Professor*
J. Arthur Ainsworth, B.S., M.S., *Associate Professor*
Horton Brown, B.S., *Associate Professor*
Elliot F. Humiston, Jr., S.B., *Assistant Professor*
Kenneth L. Rogers, B.S., *Assistant Professor*
Frederick B. Bischoff, B.S., M.S., *Instructor*
Marcellin D. Desrosiers, B.S., *Instructor*
Bernard C. Harcourt, B.S., M.A., *Instructor*
James A. Irvine, B.T.E., *Instructor*

DIVISION OF GENERAL STUDIES

John R. Robertson, A.B., A.M., *Professor, Chairman of Division, and in charge of Department of Social Sciences*

Department of Air Science

Lt. Col. Benjamin C. McCary, B.S., M.S., *Professor, in charge of Department*
Capt. Frank B. Amado, A.A., *Assistant Professor*
Capt. Kenneth J. Cahill, B.A., *Assistant Professor*
Capt. Thomas E. Convery, B.S., M.Ed., *Assistant Professor*
1st Lt. John P. Chervenak, B.S., *Assistant Professor*
T/Sgt. Timothy A. Donahue, *Instructor*
T/Sgt. Jose M. Treto, *Instructor*
S/Sgt. Lucien E. Fecteau, *Instructor*
S/Sgt. Norman C. Lombardi, *Instructor*
S/Sgt. Lawrence D. Wallace, *Instructor*

Department of Languages and Humanities

Lester H. Cushing, A.B., Ed.M., *Professor, in charge of Department*
James G. Dow, A.B., *Professor*
Wentworth Williams, B.A., Ed.D., *Professor*
John J. MacLaughlan, Ph.B., A.M., *Associate Professor*
Howard K. Moore, A.B., A.M., Ph.D., *Assistant Professor*
David B. Morey, B.S., M.A., *Assistant Professor*
Waldo W. Yarnall, B.S., *Assistant Professor*
William S. Harrison, A.B., *Instructor*
Charles E. Jarvis, B.S., M.A., *Instructor*
Thomas Higgins, B.A., M.A., *Instructor* (on leave of absence)
Gerard W. O'Connor, B.A., *Instructor*
A. James Oliver, B.S., *Instructor*
John J. Riley, A.B., A.M., *Instructor*

Department of Physical Education

LESTER H. CUSHING, A.B., Ed.M., *Professor, Director of Athletics*
DAVID B. MOREY, B.S., M.A., *Assistant Professor and Coach*
WALDO W. YARNALL, B.S., *Assistant Professor and Coach*
A. JAMES OLIVER, B.S., *Instructor and Coach*

Department of Social Sciences

JOHN R. ROBERTSON, A.B., A.M., *Professor, in charge of Department*
STUART L. MANDELL, A.B., M.B.A., *Associate Professor*
EARL J. WATT, A.B., A.M., *Assistant Professor*
JOHN R. SANDERS, A.B., M.B.A., *Instructor*
GEORGE J. TOSCANO, B.S., *Instructor*

DIVISION OF TEXTILES

JACOB K. FREDERICK, JR., B.S., *Professor, Chairman of Division, and in charge of Department of Evaluation*

Department of Fabrics

VITTORIA ROSATTO, B.S., *Professor, in charge of Department*
HERMANN H. BACHMANN, *Professor Emeritus*
RUSSELL M. FOX, *Professor Emeritus*
MARTIN J. HOELLRICH, *Professor Emeritus*
EDWARD L. GOLEC, B.S., *Associate Professor*
NATHANIEL E. JONES, *Associate Professor*
JOHN L. MERRILL, B.T.E., *Associate Professor*
GEORGE G. ARMSTRONG, JR., *Assistant Professor*
ALBERT T. WOIDZIK, B.S., *Assistant Professor*

Department of Fibers and Yarns

CHAPIN A. HARRIS, B.S., Ph.D., *Professor, in charge of Department*
JAMES H. KENNEDY, JR., B.T.E., M.S., *Professor Emeritus*
GILBERT R. MERRILL, B.T.E., *Professor Emeritus*
RUSSELL L. BROWN, B.S., *Associate Professor*
JOHN A. GOODWIN, B.T.E., M.S., *Associate Professor*
CLARENCE J. POPE, B.S., M.S., *Associate Professor*
J. FREDERIC BURTT, B.T.E., M.S., *Assistant Professor*
FRITZ F. KOBAYASHI, *Assistant Professor*
DAVID H. PFISTER, B.S., M.S., *Assistant Professor*
KENNETH S. MERRILL, B.S., *Instructor*

Department of Finishing

JOHN J. MCDONALD, B.T.C., M.S., *Professor, in charge of Department*
C. LEONARD GLEN, *Professor Emeritus*
WINFORD S. NOWELL, B.M.E., *Associate Professor*
ROBERT E. MORRISON, B.S., *Instructor*

Department of Evaluation

JACOB K. FREDERICK, JR., B.S., *Professor, in charge of Department*
DAVID H. PFISTER, B.S., M.S., *Assistant Professor*

INTRODUCTION

Lowell Technological Institute, founded in 1895, is situated in Lowell, Massachusetts, 25 miles north of Boston. Classes were formally begun on January 30, 1897 leading to certificates and diplomas in the institution then known as the Lowell Textile School. In 1913, it was granted the right to give four-year degrees in textile engineering and textile chemistry, and in 1928 the name was changed to the Lowell Textile Institute. With subsequent expansion of curriculum in diversified engineering fields, the Institute's name again was changed in 1953 to the Lowell Technological Institute. It has been under the jurisdiction of the Commonwealth of Massachusetts since 1918 and is managed by a Board of Trustees appointed by the Governor.

The Institute grants Bachelor of Science, Master of Science, and Doctor of Philosophy degrees. It is a member of the New England Association of Colleges and Secondary Schools. This membership is considered the equivalent of regional accreditation by the United States Department of Education and by the Armed Forces. The Engineers' Council for Professional Development extends full accreditation to the curricula in textile engineering.

Total value of the scientific and industrial equipment used in the instructional and research programs of the Institute is approximately $12,500,000. The campus, overlooking the Merrimack River, is composed of 10 main buildings, and an electronics and plastics engineering building currently is under construction.

The Alumni Memorial Library, with a book stack capacity of 80,000 volumes, houses one of the most complete collections of textile books in the world as well as many special collections in the fields of paper, leather, chemistry, electronics, and plastics. It serves also as a depository for U. S. Government publications and is available to industrial concerns through its Industrial Corporate Membership program.

Under a cooperative arrangement, students at Lowell Technological Institute and at the Massachusetts Institute of Technology have the mutual use of textile libraries at both institutions.

An Evening Division program leads to an associate degree in engineering or in science. There is a Summer School session offering professional advancement courses for industry, undergraduate credit courses for college students with course deficiencies, and pre-college refresher courses for incoming freshmen at the Institute.

The Ph.D. degree program is offered in the field of chemistry.

The M.S. degree is offered in the fields of chemistry, electronic engineering, leather engineering, paper engineering, textile chemistry, and textile engineering. The B.S. degree is offered in the fields of chemistry, electronic engineering, engineering physics, general engineering, leather engineering, nuclear engineering, paper engineering, plastics engineering, textile chemistry, textile engineering (engineering option), textile engineering (general manufacturing option), textile sales and management, and textile technology. The course in textile sales and management is being discontinued and is not available to new students.

The Lowell Technological Institute Research Foundation, established in 1950, conducts research, development, and consulting programs under contract with government agencies and industrial organizations. National headquarters and research facilities of the American Association of Textile Chemists and Colorists also are maintained at the Institute.

The Air Force R.O.T.C. program is compulsory for all able-bodied, nonveteran male freshmen and sophomores. Cadets completing the advanced course in the junior and senior years are awarded commissions at graduation as second lieutenants in the U. S. Air Force Reserve.

All male students must live in the residence halls at the Institute or in the fraternity houses, unless excused by the Dean of Students. Dining facilities are available at the college, but their use is not required.

Four fellowships valued at $5100 and 115 scholarships with a value of $27,000 are available to qualified students. Many of the scholarships are open to freshmen. At present, no scholarships are open to students from other countries.

The Institute conducts a Placement Office. Health services are provided by a resident nurse, with local physicians and specialists as required. The Institute is within a short distance of three modern hospitals. The city of Lowell has numerous Catholic, Protestant, Jewish, Greek Orthodox and other places of worship, many in the immediate vicinity of the Institute.

The Student Council is the chief governing body for student affairs and also coordinates the management of the 24 student activities which include religious groups, nationally affiliated professional societies, sports associations, and recreational organizations. The Interfraternity Council fosters the common interests of the four fraternity chapters, and there is an active sorority.

GENERAL REGULATIONS

Requirements for Admission

The Admissions Officers, in conjunction with the Committee on Admissions, review all applications to determine the eligibility of each candidate for matriculation. The final decision as to the eligibility of an applicant shall be left to the discretion of the Institute.

The conditions under which an applicant may be accepted are as follows:

1. A candidate for admission must be a graduate of a secondary school approved by the New England Entrance Certificate Board, the Regents of the State of New York, or a board of equal standing.

2. Because of the specialized nature of the various curricula at Lowell Technological Institute, it has been deemed advisable that all entering students shall have completed the following units of secondary-school study:

algebra (quadratics and beyond)	2 units
plane geometry	1 unit
trigonometry	½ unit
English	4 units
American history	1 unit
chemistry (including laboratory)	1 unit
or	
physics (including laboratory)	1 unit

In addition to these prerequisites, each applicant must offer credit in elective subjects, the combined prerequisites and electives totalling at least 15½ Carnegie units. In exceptional cases, some of the above requirements may be waived.

3. Candidates must complete the Scholastic Aptitude Test of the College Entrance Examination Board. They should apply directly to the College Entrance Examination Board, P. O. Box 592, Princeton, N. J.

4. Applicants for scholarship assistance must file a formal scholarship application with the Dean of Students prior to June 1.

5. Transfer students must submit transcripts of their college record, a copy of their college catalogue, and letters of honorable dismissal well in advance of their planned transfer date.

Students from Other Countries

Foreign applicants up to 5% of the total number of students in any given class (freshman, sophomore, etc.) are accepted for admission each year. Foreign candidates are urged to have the transcripts of their secondary school and/or college records, as well as all other admission materials, submitted, in English, *not less than 12 months in advance of the expected date of enrollment.* Students from 37 other countries have been awarded degrees by the Institute.

Academic Grades

The students' grades are reported by letter as follows:

A	90-100	F	Below 60, Failure
B	80-89	I	Incomplete
C	70-79	W	Withdrawn
D	60-69	X	Dropped

The student's semester rating is a weighted value used to denote his relative standing. The point values assigned are A = 4 points, B = 3 points, C = 2 points, D = 1 point and F = 0 points. These point values, when multiplied by the credit hours assigned to the subject and added together, are divided by the sum of the credit hours to give the student's semester rating. The cumulative rating for more than one semester will be obtained in the same manner as the computation for the rating of a single semester.

Dean's List

The Dean's List is composed of those students who have a semester rating of 3.00 or higher, with no current failures.

Probation

A student is placed on probation when his semester rating is below 1.25. The probationary period covers the entire semester following the issuance of the semester rating which placed the student on probation.

A student on probation may not represent the Institute in any public function and may not hold class or other offices during his term of probation.

A student with a rating of less than 1.25 for two consecutive semesters shall be dropped from the Institute for at least one semester.

If a student receives a semester rating below 0.50, he shall be automatically dropped from the Institute without benefit of a probationary period.

Requirements for Graduation

Only those students who have satisfied the following minimum requirements will be recommended for the baccalaureate:

(1) Complete successfully one of the prescribed curricula with no substitutions for major subjects therein and no unremoved failures in a major subject.

(2) Earn a cumulative rating of 1.5 or better for the entire period at the Institute.

(3) Pass 80% of the credit hours offered towards the degree with grades higher than D.

Graduation Honors

Academic honors are awarded at Commencement as follows:

"With Honors"—a rating of 3.00-3.49 for the entire period of study at the Institute;

"With High Honors"—a rating of 3.5 or better for the entire period of study at the Institute;

"With Highest Honors"—a rating of 3.8 or better and completion of at least six semesters of work at the Institute.

Summary of Expenses Per Year

Tuition (residents of Massachusetts)	$150
Tuition (residents of other states and U. S. possessions)	250
Tuition (residents of other countries)	500
Dormitory rate	275
Laboratory and Materials Fee	
(a) All freshmen	24
(b) Upperclassmen enrolled in:	
Textile Technology, Textile Engineering, Textile Sales, General Engineering, Engineering Physics, Electronic Engineering or Nuclear Engineering	24
Paper, Leather, or Plastics Engineering	34
Chemistry or Textile Chemistry	44
Student Activity and Insurance Fee	40
ROTC Deposit	25
*Books and supplies	50

Students may take their meals in the college cafeteria or in any of the neighboring restaurants. In general, $800 is the total estimated cost of room and board for the academic year.

*Books and supplies for the first year cost about $80, second and third year $35, and fourth year $50, thus averaging about $50 per year for the four years.

COURSES OF STUDY

UNDERGRADUATE PROGRAMS

Twelve fields of study* are open to undergraduates. All are four years in length and lead to the degree of Bachelor of Science. These fields are:

- Chemistry
- Electronic Engineering
- Engineering Physics
- General Engineering
- Leather Engineering
- Nuclear Engineering
- Paper Engineering
- Plastics Engineering
- Textile Chemistry
- Textile Engineering—Engineering Option
- Textile Engineering—General Manufacturing Option
- Textile Sales and Management*
- Textile Technology

These curricula, outlined in the following pages, are under constant study and are subject to revision whenever changes are necessary to enable the Institute better to fulfill its mission of service to industry.

In all courses considerable work in practical industrial applications has been included in addition to the fundamental studies in the physical sciences, mathematics, and engineering. Classes in the humanities and social sciences have been woven into all curricula in a conscious effort to produce graduates not only with a thorough technical training but also with the broad cultural background which marks the educated man.

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*The curriculum in Textile Sales and Management is being discontinued and is not available to new students.

The Freshman Program

Orientation

The first week's program in the fall for entering freshmen is called Freshman Week. It is devoted to facilitating the adjustment of the new student to his physical and social surroundings. Under the sponsorship of the Office of the Dean of Students, a program of meetings, lectures and conferences is presented in order to acquaint the entering class with the traditions, customs, rules and regulations, courses of instruction, organizations, recreational activities and other facilities of Lowell Technological Institute.

All new students are required to attend the program of Freshman Orientation which carries no academic credits but is designed to make the freshman aware of his new responsibilities and to help him adjust to college life. It guides him in making the most efficient use of his time and talents, attempts to develop his ability to think and to react thoughtfully and intelligently to new ideas and viewpoints.

Freshman Course of Study

First Semester

*AS	101	Air Science	(2-1)2
CH	101	General Chemistry	(4-2)4
EN	113	Engineering Graphics	(0-3)1
GS	111	English Composition and Reading	(3-0)3
MA	107	Introduction to Mathematical Analysis	(4-0)4
PH	103	Physics	(4-1)4
		Total credit hours	18

Second Semester

*AS	102	Air Science	(2-1)2
CH	102	General Chemistry	(4-2)4
EN	114	Engineering Graphics	(0-3)1
GS	112	English Composition and Reading	(3-0)3
MA	108	Calculus and Analytic Geometry	(5-0)5
PH	104	Physics	(4-1)4
		Total credit hours	19

In addition to the preceding schedule all nonveteran men students who are physically qualified must take physical education for the whole freshman year. This subject meets one hour per week for AFROTC students and two hours per week for all others. It carries no academic credit.

*Required of all able-bodied, nonveteran male citizens (see page 12). Other students must take in its place GS 101-102, World Economic Geography.

The Elective System

In all curricula an opportunity is afforded the student to elect subjects in addition to those required for graduation. These electives fall into two categories: technical electives and general electives.

Technical electives give the student a chance to broaden his professional knowledge by taking subjects allied to his main interest or to further his knowledge of a particular phase by taking additional work therein.

General electives are subjects offered by the Division of General Studies. They include cultural courses in the humanities or social sciences, or management courses to help fit the graduate for positions of executive responsibility. Normally all general electives taken by a student as an undergraduate must be chosen from one of the five cores listed below. However, in particular cases and with the division chairman's permission elective work may be divided between two cores.

I. Management Core

GS 301	Economic Development of the United States	(3-0)3
GS 302	Modern Labor Problems	(3-0)3
GS 461	Personnel Management	(3-0)3
GS 463	Business Law	(3-0)3
GS 465	Management Problems	(3-0)3

II. Finance Core

GS 313	Money and Banking	(3-0)3
GS 341	Accounting I	(3-0)3
GS 342	Accounting II	(3-0)3
GS 468	Business Finance	(2-0)2
Elective		(3-0)3

III. Sales Core

GS 321	Marketing Principles and Problems	(3-0)3
GS 322	Marketing Principles and Problems	(3-0)3
GS 442	Foreign Trade	(3-0)3
GS 443	Advertising Principles and Problems	(3-0)3
Elective		(3-0)3

IV. Literature Core

GS 222	Appreciation of Literature	(3-0)3
GS 232	Comparative Literature	(3-0)3
GS 473	Modern Drama	(3-0)3
GS 475	The Modern American Novel	(3-0)3
Elective		(3-0)3

V. History and Government Core

GS 223	The United States since 1865	(3-0)3
GS 226	World History since 1900	(3-0)3
GS 301	Economic Development of the United States	(3-0)3
GS 469	Comparative Modern Governments	(3-0)3
GS 471	American Foreign Policy, 1774 to the Present	(3-0)3

Chemistry

Those who make Chemistry their field of concentration are provided with a basic knowledge of the four major branches of chemistry, inorganic, organic, analytical, and physical, and with advanced instruction in one or more of the same areas, to prepare either for positions in the chemical industry or for further training at the graduate level.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201M	Organic Chemistry	(3-6)5
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202M	Organic Chemistry	(3-6)5
CH	206	Qualitative Analysis	(2-6)4
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	307	Atomic and Molecular Structure	(3-0)3
CH	331	Physical Chemistry	(3-3)4
GS	201	Economics	(3-0)3
GS	261	Technical German	(3-0)3
AS	301	Air Science, or General Elective	2 to 4
		Technical Elective	3
		Total credit hours	18 to 20

Second Semester

CH	314	Advanced Quantitative Analysis	(2-4)3
CH	332	Physical Chemistry	(3-3)4
GS	202	Economics	(3-0)3
GS	262	Technical German	(3-0)3
AS	302	Air Science, or General Elective	2 to 4
		Technical Elective	3
		Total credit hours	18 to 20

SENIOR YEAR

First Semester

CH	423 or 431 or 443	Advanced Chemistry	(3-0)3
AS	401	Air Science, and one General Elective; or two General Electives	6 or 7
		Technical Electives	6
		Total credit hours	15 or 16

Second Semester

CH	424 or 432 or 444	Advanced Chemistry	(3-0)3
AS	402	Air Science, and one General Elective; or two General Electives	6 or 7
		Technical Electives	6
		Total credit hours	15 or 16

Recommended Technical Electives for juniors and seniors: CH 333, 334, 342, 352, 403-404, 446, and 481; PH 302, 322, and 504; for seniors only: CH 408-409, 423-424, 431-432, and 443-444.

Recommended General Electives: GS 222, 223, 226, 232, 301, 302, 303, 469 or 470, 471 or 472, 473, and 475.

NOTE: For explanation of the Elective System, see page 18.

and religions are represented in the enrollment. Although the majority of its students are men, the Institute is co-educational.

Campus

The Institute is located 25 miles north of Boston in Lowell, Massachusetts, a city of nearly 100,000, long famous as a textile center and more recently noted for its increasingly diversified industries. The 25-acre campus, situated on the Merrimack River, includes eleven main buildings, among them the library, an auditorium-administration building, six classroom-laboratory buildings, two residence halls, and a power plant. A $4,500,000 nuclear center and a $2,120,000 physical education building are under way.

Alumni Memorial Library

The library, dedicated to alumni of the Institute who served in World Wars I and II and the Korean conflict, was erected in 1951 by the Alumni Association through contributions from alumni and friends. Besides a book stack capacity of 80,000 volumes, it contains student activity offices and alumni headquarters and houses one of the world's most complete collections of textile books as well as numerous special collections in the fields of paper, leather, and plastics. It also serves as a depository for U. S. government publications and is available to industrial concerns through its Industrial Corporate Membership program.

Equipment

Laboratory equipment used in the instructional and research programs of the Institute is valued at more than $10,000,000. It includes such varied apparatus as an electron microscope, analog and digital computers, and full-sized industrial machines as well as complete pilot-plant facilities in all technological areas, paper, plastics, leather, and textiles.

ADMISSION OF UNDERGRADUATES

New students are selected from those applicants who during their preparatory education have shown academic promise and strength of character. Besides scholastic rating and test results, high value is placed upon their evidence of leadership and contribution to school and community life.

Application for admission should be made as soon as possible after the first marking period in the candidate's senior year of secondary school. Applicants who apply before the first marking period will not be considered until the Admissions Office has received senior grades for this period. The responsibility of having these marks forwarded to Lowell Technological Institute rests with the applicant. Students from other countries are advised to start the application procedure not less than 12 months in advance of the expected date of enrollment.

Correspondence is welcomed prior to their senior year from students in high school who may require help in adapting their secondary-school programs to fit the needs of the freshman year at the Institute. Requests for application blanks and all correspondence relating to matriculation should be addressed to the Director of Admissions, Lowell Technological Institute, Lowell, Mass. 01854.

Applications for admission must be received by the Institute on or before June 1, prior to the September in which the applicant wishes to matriculate.

All admission records, once submitted, become the property of the Institute and cannot be returned.

An applicant who is in need of financial assistance may request an application for a loan under the National Education Defense Act or an application for scholarship aid AFTER he has been accepted for admission to Lowell Technological Institute.

Application Procedure

A candidate for admission should:

1. Complete the first two pages of the admission application form.

2. Attach a certified check or money order in payment of the application fee of $10 and is not refundable.

3. Submit the entire application form to the office of his secondary-school principal, with a request that the office fill out

Second Semester

EL	402	Servomechanisms	(3-0)3
EL	412	Applied Electronics Laboratory	(0-4)2
EL	414	Thermodynamics and Properties of Materials	(3-0)3
AS	402	Air Science, and one Technical Elective; or two Technical Electives	6 or 7
		Total credit hours	14 or 15

Technical Electives

EL	404	Microwave Electronics	(3-0)3
EL	410	Electronic Projects Laboratory	(0-4)2
EL	416	Communications Theory	(3-0)3
EL	418	Network Analysis	(3-0)3
EL	420	Instrumentation	(3-0)3
EL	426	Special Topics in Electronics	(3-0)3

NOTE: For explanation of the Elective System, see page 18.

Engineering Physics

This program was developed to meet the demands of industry, education, and government for people with an intensive training in physics and mathematics and the ability to put their knowledge to use in helping to solve some of the problems of the current crisis in science, as researchers or teachers. It is intended to challenge the student to his greatest achievements and should not be contemplated by any who do not find themselves on the best of terms with mathematics.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
GS	261	Technical German	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
PH	211	Intermediate Mechanics	(3-0)3
PH	251	Intermediate Electricity	(3-3)4
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
GS	262	Technical German	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
PH	222	Intermediate Thermodynamics	(3-0)3
PH	254	Electronics	(3-3)4
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-1½)4
MA	301	Advanced Calculus	(3-0)3
PH	323	Statistical Mechanics	(3-0)3
PH	355	Physical Electronics	(3-3)4
PH	361	Intermediate Nuclear Physics	(3-0)3
AS	301	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

Second Semester

CH	332	Physical Chemistry	(3-3)4
MA	302	Advanced Calculus	(3-0)3
PH	312	Physical Mechanics	(3-0)3
PH	354	Electromagnetic Theory	(3-0)3
PH	358	Electrical Measurements	(2-3)3
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

MA	403	Mathematical Techniques in Physical Sciences	(3-0)3
PH	411	Quantum Mechanics	(3-0)3
PH	443	Spectroscopy	(2-3)3
PH	461	Nuclear Physics	(3-0)3
PH	471	Solid State Physics	(3-0)3
AS	401	Air Science, or Elective	3 or 4
		Total credit hours	18 or 19

Second Semester

MA	404	Mathematical Techniques in Physical Sciences	(3-0)3
PH	412	Quantum Mechanics	(3-0)3
PH	462	Nuclear Physics	(3-3)4
PH	472	Solid State Physics	(3-3)4
AS	402	Air Science, or Elective	4
		Total credit hours	18

NOTE: For explanation of the Elective System, see page 18.

General Engineering

The General Engineering curriculum is designed to give the student a fundamental preparation for a wide variety of positions in industry, because of industry's growing need for men who are versatile in their engineering capabilities, soundly trained in the basic principles which underlie all engineering, and therefore adaptable to assignment to numerous positions in modern industrial organizations.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	203	Mechanism	(3-0)3
EN	207	Machine Drawing	(0-6)2
EN	211	Machine Tool Laboratory	(1-2)1
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	222	Applied Mechanics I	(3-0)3
EN	232	Engineering Materials	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	18

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	301	Applied Mechanics II	(3-0)3
EN	303	Electrical Circuits	(3-2)3
EN	305	Thermodynamics	(3-0)3
GS	201	Economics	(3-0)3
AS	301	Air Science, and one Technical Elective; or two Technical Electives	6 to 8
		Total credit hours	18 to 20

Technical Electives

CH	331	Physical Chemistry	(3-3)4
EN	307	Surveying and Structures	(3-3)4
EN	309	Metals Processing	(2-2)3
EN	313	Advanced Mechanism	(2-2)3
MA	301	Advanced Calculus	(3-0)3

Second Semester

EN	302	Applied Mechanics III	(3-0)3
EN	316	Heat Engineering	(3-3)4
PH	322	Electronics	(3-2)4
AS	302	Air Science, and one Technical Elective; or one General and one Technical Elective	6 to 8
		Total credit hours	17 to 19

Technical Electives

CH	332	Physical Chemistry	(3-3)4
CH	352	Chemical Engineering	(3-0)3
EN	308	Structures	(3-0)3
MA	302	Advanced Calculus	(3-0)3

SENIOR YEAR

First Semester

EN	351	Statistical Methods	(3-0)3
EN	401	Principles of Electrical Engineering	(3-2)4
GS	211	Business English	(2-0)2
GS	341	Accounting I	(3-0)3
AS	401	Air Science, and one Elective; or two Electives	6 or 7
		Total credit hours	18 or 19

Electives

CH	441	Chemical Engineering	(3-0)3
EN	411	Advanced Heat Engineering	(3-2)4
EN	427	Machine Design	(2-3)3
EN	501	Statistical Quality Control	(3-0)3
EN	505	Experimental Stress Analysis	(2-3)3
PH	503	Spectrographic Methods	(2-3)3

Second Semester

EN	406	Fluid Mechanics	(3-2)4
EN	420	Industrial Instrumentation	(2-3)3
GS	412	Industrial Management	(3-0)3
AS	402	Air Science, and/or Electives	7 or 8
		Total credit hours	17 or 18

Electives

EN	402	Electrical Control Systems	(3-2)4
EN	404	Heat Transfer	(3-0)3
EN	428	Machine Design	(2-3)3
EN	442	Air Conditioning	(2-2)2
PH	506	X-ray Diffraction	(2-3)3
PH	508	Electron Microscopy	(1-3)2

NOTE: For explanation of the Elective System, see page 18.

Leather Engineering

The Leather Engineering course has been designed to graduate engineers with a thorough understanding of the art of leather manufacturing, aware that many products of the leather industry can be improved by the application of sound and intelligent research and development. The economics, size, and scope of the leather industry warrant the careful training of individuals capable of handling its specific problems.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	205	Qualitative Analysis	(2-6)4
EN	325	Applied Mechanics	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	21

*Alternate:

GS	201	Economics	(3-0)3

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	212	Quantitative Analysis	(3-6)5
EN	352	Statistical Methods	(3-0)3
LE	202	Applied Leather Analysis	(1-4)2
		General Elective	(3-0)3
		Total credit hours	19

*Alternate:

GS	202	Economics	(3-0)3

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-3)4
EN	331	Strength of Materials	(3-0)3
LE	301	Leather Technology	(3-6)5
LE	303	Leather Histology	(2-4)4
AS	301	Air Science, or GS 341, Accounting I	3 or 4
		Total credit hours	19 or 20

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	334	General Colloid Chemistry	(3-0)3
LE	302	Leather Technology	(3-6)5
LE	304	Leather Microbiology	(2-4)4
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

LE	401	Leather Technology	(3-6)5
LE	405	Leather Seminar	(1-0)1
LE	411	Leather Problems	(1-6)3
PH	321	Electronics	(3-1)3
AS	401	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	18 or 19

Second Semester

EN	344	Electrical Machinery	(3-2)4
LE	402	Leather Technology	(3-6)5
LE	404	Properties of Leather	(2-3)3
LE	406	Leather Seminar	(1-0)1
LE	412	Leather Problems	(1-6)3
AS	402	Air Science, or General Elective	3 or 4
		Total credit hours	19 or 20

NOTE: For explanation of the Elective System, see page 18.

Nuclear Engineering

The program in Nuclear Engineering, first to be offered by a publicly supported institution in New England, is planned to give the graduates a broad engineering education, with sufficient grounding in the specialized nuclear field to enable them to accept positions of responsibility and leadership in this rapidly growing industry.

PROTOTYPE CURRICULUM

SOPHOMORE YEAR

Similar to curriculum in Engineering Physics

JUNIOR YEAR

First Semester

Advanced Calculus	(3-0)3
Physical Chemistry	(3-1½)4
Properties of Materials	(2-3)3
Nuclear Control Electronics	(3-3)4
Radiation Physiology	(2-2)3
Humanities Elective	(3-0)3

Second Semester

Advanced Calculus	(3-0)3
Physical Chemistry	(3-3)4
Intermediate Nuclear Physics	(3-0)3
Electrical Measurements	(2-3)3
Heat Engineering	(3-3)4
Radiation Physiology	(3-0)3

SENIOR YEAR

First Semester

Mathematical Techniques	(3-0)3
Physical Mechanics	(3-0)3
Solid State Physics	(3-0)3
Nuclear Physics	(3-3)4
Servomechanisms	(3-3)4
Elective	(3-0)3

Second Semester

Radioisotope Techniques	(3-3)4
Quantum Mechanics	(3-0)3
Solid State Physics	(3-3)4
Nuclear Systems	(3-6)5
Elective	(3-0)3

Paper Engineering

The object of the Paper Engineering course is to fit a man for work in the papermaking, paper-converting, or allied industries. A thorough training in basic chemical engineering is offered, accompanied by instruction in the theory and practice of pulp and paper manufacture and paper converting. Paper engineering involves the application of cellulose and plastics chemistry together with engineering principles to the handling of the material in the web or sheet form, as it is treated, coated, or converted into the final product.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	290	Introduction to Chemical Engineering	(3-3)4
EN	326	Applied Mechanics	(3-0)3
EN	352	Statistical Methods	(3-0)3
GS	214	Communication of Ideas	(3-0)3
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-3)4
CH	333	Industrial Stoichiometry	(3-0)3
PA	301	Pulp Technology	(3-0)3
PA	303	Pulp Laboratory	(2-6)4
PH	321	Electronics	(3-1)3
AS	301	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	334	General Colloid Chemistry	(3-0)3
CH	352	Chemical Engineering	(3-0)3
PA	302	Paper Technology	(3-0)3
PA	304	Paper Laboratory	(2-6)4
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

SENIOR YEAR

First Semester

CH	441	Chemical Engineering	(3-0)3
PA	403	Converting Technology	(3-0)3
PA	405	Converting Laboratory	(2-6)4
PA	409	Mill Inspections	(1-4)2
AS	401	Air Science, and one General Elective; or two General Electives	6 or 7
		Total credit hours	18 or 19

Second Semester

CH	442	Chemical Engineering Thermodynamics	(3-0)3
EN	344	Electrical Machinery	(3-2)4
EN	352	Statistical Methods	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
PA	414	Paper Problems	(2-6)4
AS	402	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

NOTE: For explanation of the Elective System, see page 18.

Plastics Engineering

The training of engineers specifically prepared to cope with the many technical and production problems found in the expanding field of plastics fabrication is the objective of the course in Plastics Engineering. Emphasis is on the engineering principles involved in the fabrication of plastic materials into useful forms rather than the chemistry involved in the manufacture of the plastic material itself. However, the curriculum involves considerably more chemistry than most engineering courses, owing to the close relationship between the physical and chemical properties of such materials. Problems of design, manufacture and testing in the plastics industry are closely studied.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	205	Qualitative Analysis	(2-6)4
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	18

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	212	Quantitative Analysis	(3-6)5
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
		Total credit hours	18

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-3)4
EN	211	Machine Tool Laboratory	(1-2)1
EN	325	Applied Mechanics	(3-0)3
EN	405	Electronic Controls and Power Circuits	(3-2)4
PL	301	Introduction to Plastics Technology	(3-3)4
AS	301	Air Science, or GS 201, Economics	3 or 4
		Total credit hours	19 or 20

Second Semester

CH	332	Physical Chemistry	(3-3)4
EN	232	Engineering Materials	(3-0)3
EN	234	Plastics Mold Design and Construction	(1-2)1
EN	332	Strength of Materials	(3-0)3
PL	302	Introduction to Plastics Technology	(3-3)4
AS	302	Air Science, or GS 202, Economics	3 or 4
		Total credit hours	18 or 19

SENIOR YEAR

First Semester

CH	403	Chemistry of High Polymers	(3-3)4
PL	401	Advanced Plastics Technology	(2-3)3
PL	403	Properties of Polymers	(2-3)3
PL	411	Plastics Seminar	(1-0)1
AS	401	Air Science, and one Elective; or two Electives	6 or 7
		Total credit hours	17 or 18

Second Semester

CH	404	Chemistry of High Polymers	(3-3)4
EN	408	Fluid Mechanics	(3-0)3
EN	422	Industrial Instrumentation	(2-0)2
PL	402	Advanced Plastics Technology	(2-3)3
PL	404	Properties of Polymers	(2-3)3
PL	412	Plastics Seminar	(1-0)1
AS	402	Air Science, or one Elective	3 or 4
		Total credit hours	19 or 20

Electives

CH	307	Atomic and Molecular Structure	(3-0)3
CH	423-424	Advanced Organic Chemistry	(3-0) (3-0)6
EN	203	Mechanism	(3-0)3
EN	502	Statistical Quality Control	(3-0)3
EN	509 or 510	Advanced Statistical Methods	(3-0)3
GS	261-262	Technical German	(3-0)(3-0)6
MA	206	Differential Equations	(3-0)3

NOTE: For explanation of the Elective System, see page 18.

Textile Chemistry

A sound foundation in basic chemistry and a knowledge of chemical applications in textiles and in textile processes are combined in the Textile Chemistry course to provide a specialized training for chemists planning to work in the textile industry or in related chemical industries producing auxiliary chemicals and fibers.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201M	Organic Chemistry	(3-6)5
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202M	Organic Chemistry	(3-6)5
CH	206	Qualitative Analysis	(2-6)4
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	311	Advanced Quantitative Analysis for Textile Chemists	(2-4)3
CH	331	Physical Chemistry	(3-3)4
CH	355	Chemistry and Physics of Fibers	(2-3)3
GS	201	Economics	(3-0)3
TE	327	Elements of Textile Manufacture	(2-2)3
AS	301	Air Science, or General Elective	2 to 4
		Total credit hours	18 to 20

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	356	Chemistry of Fiber Purification	(2-3)3
CH	364	Textile Colloid Chemistry	(4-0)4
GS	202	Economics	(3-0)3
TE	328	Elements of Textile Manufacture	(2-2)3
AS	302	Air Science, or General Elective	2 to 4
		Total credit hours	19 to 21

SENIOR YEAR

First Semester

CH	425	Organic Chemistry of Colored Substances	(2-0)2
CH	453	Theory of Dyeing	(3-4)4
TE	403	Textile Evaluation	(2-2)3
TE	429	Finishing—Cotton and Synthetics	(2-1)2
TE	439	Finishing—Woolen and Worsted	(2-1)2
AS	401	Air Science, or Electives	6 or 7
		Total credit hours	19 or 20

Second Semester

CH	422	Chemical Textile Testing	(2-3)3
CH	454	Industrial Dyeing and Printing	(2-8)4
TE	430	Finishing—Cotton and Synthetics	(1-2)2
TE	440	Finishing—Woolen and Worsted	(1-2)2
AS	402	Air Science, or Electives	6 or 7
		Total credit hours	17 or 18

Recommended technical electives are: CH 333, 334, 342, 352, 403-404. 408-409, 423-424, 431-432, 443-444, 446, 481; MA 206; PH 302, 322, 504.

NOTE: For explanation of the Elective System, see page 18.

Textile Engineering

Engineering Option

A textile engineer is one who has had a basic training in engineering to which has been added a knowledge of the manufacture of textiles, their properties and uses. The Engineering Option of Textile Engineering provides a training in mechanical engineering similar to that found in other engineering schools, plus a knowledge of textiles sufficient to prepare the individual for a position in the textile and allied industries which may involve research and engineering principles.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	203	Mechanism	(3-0)3
EN	207	Machine Drawing	(0-6)2
EN	211	Machine Tool Laboratory	(1-2)1
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	222	Applied Mechanics I	(3-0)3
EN	232	Engineering Materials	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	18

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	301	Applied Mechanics II	(3-0)3
EN	305	Thermodynamics	(3-0)3
EN	351	Statistical Methods	(3-0)3
PH	321	Electronics	(3-1)3
TE	327	Elements of Textile Manufacture	(2-2)3
AS	301	Air Science, or GS 201, Economics	3 or 4
		Total credit hours	18 or 19

Second Semester

EN	302	Applied Mechanics III	(3-0)3
EN	316	Heat Engineering	(3-3)4
EN	342	Principles of Electrical Engineering	(3-2)4
TE	328	Elements of Textile Manufacture	(2-2)3
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	17 or 18

SENIOR YEAR

First Semester

EN	401	Principles of Electrical Engineering	(3-2)4
GS	209	Speech	(2-0)2
GS	211	Business English	(2-0)2
GS	341	Accounting I	(3-0)3
TE	403	Textile Evaluation	(2-2)3
AS	401	Air Science, and one Technical Elective; or two Technical Electives	6 or 7
		Total credit hours	20 or 21

Technical Electives

EN	427	Machine Design	(2-3)3
EN	429	Engineering Design of Textile Structures	(3-0)3
PH	401	Textile Microscopy	(2-3)3
PH	503	Spectrographic Methods	(2-3)3
TE	449	Finishing Technology	(2-2)3

Second Semester

EN	408	Fluid Mechanics	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
GS	412	Industrial Management	(3-0)3
TE	404	Textile Evaluation	(2-2)3
AS	402	Air Science, or General Elective	3 or 4
		Technical Electives	3 or 4
		Total credit hours	18 to 20

Technical Electives

EN	404	Heat Transfer	(3-0)3
EN	428	Machine Design	(2-3)3
EN	430	Engineering Design of Textile Structures	(3-0)3
EN	442	Air Conditioning	(2-2)2
PH	402	Textile Physics	(2-2)3
PH	506	X-ray Diffraction	(2-3)3
PH	508	Electron Microscopy	(1-3)2
TE	450	Finishing Technology	(2-2)3

NOTE: For explanation of the Elective System, see page 18.

Textile Engineering

General Manufacturing Option

The objective of the General Manufacturing Option of Textile Engineering is to provide the textile industry with technically trained textile engineers. Students in this program are given as complete a knowledge as possible of the raw materials, machines, and processes peculiar to the manufacture of all fibers as well as a basic training in engineering and the fundamental sciences. The course prepares the students to be useful in any textile plant, regardless of fiber processed, approaching textile problems from an engineering viewpoint.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	201	Machine Drawing	(0-3)1
EN	203	Mechanism	(3-0)3
GS	201	Economics	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
TE	203	Textile Fibers	(4-0)3
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	212	Machine Tool Laboratory	(1-2)1
EN	222	Applied Mechanics I	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
TE	206	Yarn Manufacture	(3-3)4
		General Elective	(3-0)3
		Total credit hours	20

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	203	Elementary Organic Chemistry	(3-0)3
EN	331	Strength of Materials	(3-0)3
PH	321	Electronics	(3-1)3
TE	307	Yarn Manufacture	(3-3)4
TE	309	Fabric Manufacture	(2-2)2
AS	301	Air Science, or General Elective	3 or 4
		Total credit hours	18 or 19

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
EN	344	Electrical Machinery	(3-2)4
EN	352	Statistical Methods	(3-0)3
TE	308	Yarn Manufacture	(3-3)4
TE	310	Fabric Manufacture	(3-3)4
AS	302	Air Science, or General Elective	3 or 4
		Total credit hours	20 or 21

SENIOR YEAR

First Semester

EN	403	Principles of Heat Engineering	(3-3)4
GS	341	Accounting I	(3-0)3
TE	403	Textile Evaluation	(2-2)3
TE	405	Finishing Technology	(4-2)4
AS	401	Air Science, or a Technical Elective; and one General Elective	6 or 7
		Total credit hours	20 or 21

Technical Electives

EN	429	Engineering Design of Textile Structures	(3-0)3
TE	407	Knitting	(2-3)3
TE	417	Cotton Mill Organization	(4-0)3

Second Semester

GS	210	Speech	(2-0)2
GS	212	Business English	(2-0)2
GS	412	Industrial Management	(3-0)3
TE	404	Textile Evaluation	(2-2)3
TE	406	Finishing Technology	(0-4)2
AS	402	Air Science, or a Technical Elective; and one General Elective	6 or 7
		Total credit hours	18 or 19

Technical Electives

EN	408	Fluid Mechanics	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
EN	430	Engineering Design of Textile Structures	(3-0)3

NOTE: For explanation of the Elective System, see page 18.

Textile Sales and Management

The Textile Sales and Management course is geared to those interested in the marketing and management phases of the textile and allied industries, with emphasis on all three branches of management—production, distribution, and finance. The student is given a fundamental knowledge of the natural sciences and their application to the processing of all types of textile fibers. This scientific and manufacturing background is increasingly essential to effective merchandising and management, particularly at the higher levels of supervision. This course is being discontinued and is not available to new students.

JUNIOR YEAR

First Semester

GS	311	Economic Statistics	(3-0)3
GS	321	Marketing Principles	(3-0)3
GS	341	Accounting I	(3-0)3
TE	307	Yarn Manufacture	(3-3)4
TE	309	Fabric Manufacture	(2-2)2
AS	301	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	18 or 19

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
GS	322	Marketing Problems	(3-0)3
GS	342	Accounting II	(3-0)3
TE	308	Yarn Manufacture	(3-3)4
TE	310	Fabric Manufacture	(3-3)4
AS	302	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

GS	303	Psychology	(3-0)3
GS	461	Personnel Management	(3-0)3
GS	463	Business Law	(3-0)3
TE	403	Textile Evaluation	(2-2)3
TE	405	Finishing Technology	(4-2)4
AS	401	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	19 or 20

Second Semester

GS	302	Modern Labor Problems	(3-0)3
GS	412	Industrial Management	(3-0)3
GS	442	International Trade	(3-0)3
GS	444	Sales Management	(3-0)3
TE	404	Textile Evaluation	(2-2)3
TE	406	Finishing Technology	(0-4)2
AS	402	Air Science, or Elective approved by Division Head	3 or 4
		Total credit hours	19 or 20

NOTE: For explanation of the Elective System, see page 18.

Textile Technology

This course of study is designed to equip its students with a well-rounded understanding of the theory and principles relating to the processing of textile materials. At the same time it provides the scientific basis necessary to understand and apply this technological knowledge. Basic purpose of the program is to prepare students to become competent textile technologists for eventual supervisory, administrative, or executive positions within the industry and its allied fields. To achieve this end, a comprehensive course covers the basic theory, principles, and applications of the major phases of textile manufacture utilizing all the common fibers, both natural and man-made, and all fabricating processes.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	203	Elementary Organic Chemistry	(3-0)3
EN	205	Mechanism	(3-2)4
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
TE	201	Fiber Technology	(4-0)3
		Total credit hours	20

*Alternate:

GS	205	Man and His Environment	(3-0)3

Second Semester

*AS	202	Air Science	(2-1)2
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
TE	202	Fiber Technology	(3-0)2
TE	204	Yarn Technology	(7-2)5
		Total credit hours	17

*Alternate:

GS	222	Appreciation of Literature	(3-0)3

JUNIOR YEAR

First Semester

EN	311	Heat and Power	(2-2)3
GS	201	Economics	(3-0)3
TE	301	Yarn Technology	(7-6)7
TE	303	Fabric Technology	(3-4)4
AS	301	Air Science, or GS 223, The United States since 1865	3 or 4
		Total credit hours	20 or 21

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
GS	202	Economics	(3-0)3
TE	302	Yarn Technology	(7-6)7
TE	304	Fabric Technology	(3-4)4
AS	302	Air Science, or GS 232, Comparative Literature	3 or 4
		Total credit hours	19 or 20

SENIOR YEAR

First Semester

CH	401	Introduction to Textile Chemistry	(1-3)2
TE	401	Fabric Technology	(5-7)6
TE	403	Textile Evaluation	(2-2)3
TE	405	Finishing Technology	(4-2)4
AS	401	Air Science, or GS 301, Economic Development of the United States	3 or 4
		Total credit hours	20 or 21

Second Semester

EN	304	Instrumentation for Textile Processing	(2-2)3
TE	402	Fabric Technology	(5-7)6
TE	404	Textile Evaluation	(2-2)3
TE	406	Finishing Technology	(0-4)2
AS	402	Air Science, or GS 470, Comparative Modern Governments	3 or 4
		Total credit hours	20 or 21

NOTE: For explanation of the Elective System, see page 18.

Subject Descriptions

Subjects are listed alphabetically, regardless of the department involved, under the following headings:

AS	Air Science	LE	Leather
CH	Chemistry	MA	Mathematics
EL	Electronics	PA	Paper
EN	Engineering	PH	Physics
GS	General Studies	PL	Plastics
TE	Textiles		

The number following the letter symbols is composed of three digits. The first digit of the number indicates the college year when the subject is normally presented, e.g.: GS 111 is a freshman-year subject; PA 414 is a senior-year subject. Subjects numbered 500 and above are restricted to graduate students.

First-semester subjects are designated by odd numbers and second-semester subjects by even numbers. Hyphenated numbers indicate subjects continuing throughout the year.

Following the names of the individual subjects, the number ot lecture-recitation and laboratory hours is indicated within the parentheses and the credit hour is shown outside. In the case of a year course the credit shown is the total for the year.

Examples of the above coding are as follows:

(2-6)4 means 2 hours of lecture-recitation and 6 hours of laboratory for 4 credits; (2-3) (1-6)6 indicates 2 hours of lecture-recitation and 3 hours of laboratory for the first semester followed by 1 hour of lecture-recitation and 6 hours of laboratory the second semester, for a total credit of 6.

The prerequisites for the various subjects are shown in brackets, e.g., [EN 111]. No student can be officially registered in a subject until the indicated prerequisites have been satisfactorily completed.

AIR SCIENCE

AS 101-102 **Air Science I** **(2-1)(2-1)4**

Introduction to Air Force ROTC, elements and potentials of air power, air vehicles and principles of flight, the military instrument of national security, and professional opportunities in the United States Air Force. Classes in leadership and drill provide for the development in the student of the qualities of leadership and discipline essential to Air Force officers.

AS 201-202 **Air Science II** **(2-1)(2-1)4**

Introduction to the elements and potentials of air power. The course considers air power in terms of targets, weapons, aircraft, bases, and operations. Consideration is also given to the USAF Officer Career Program and the moral responsibility of Air Force leaders.

AS 301-302 **Air Science III** **(4-1)(4-1)8**

Concerns the development of certain specialized intellectual skills in the areas of military law, command and staff, problem solving, communication, and instruction in the Air Force, and certain technical skills in the areas of weather, navigation, and air base functions.

AS 401-402 **Air Science IV** **(4-1)(4-1)8**

Seminar in principles of personnel management. The framework of international politics, world powers and strategic areas, and the security problem in relation to international power clashes. Principles of warfare and a historical survey of air warfare. Briefing for commissioned service and a leadership laboratory.

CHEMISTRY

CH 101-102 **General Chemistry** **(4-2)(4-2)8**

Chemical principles and calculations. Includes the chemistry of both metallic and nonmetallic elements and of their compounds. A brief survey of organic chemistry is included in the second semester.

CH 201-202 **Organic Chemistry** **(3-3)(3-3)8**
[CH 102]

The classification, nomenclature, structure, mechanism of reaction, and behavior in bulk of important kinds of organic species. The laboratory work illustrates the experimental techniques which can be used to react, purify, characterize, and identify organic substances.

CH 201M-202M **Organic Chemistry** **(3-6)(3-6)10**
[CH 102]

Identical with CH 201-202 except that additional laboratory work in synthetic organic chemistry is given. Required for majors in chemistry.

CH 203 **Elementary Organic Chemistry** **(3-0)3**
[CH 102]

This subject enables students not majoring in chemistry to become conversant with the names, structural formulas, properties and uses of some important industrially available organic substances and with the role which organic chemistry plays in industry and engineering.

CH 205 and 206 **Qualitative Analysis** **(2-6)4**
[CH 102]

Mass action principles and systematic analysis of inorganic compounds by semi-micro technique. Offered both semesters.

CH 211 and 212 **Quantitative Analysis** **(3-6)5**
[CH 102]

The fundamental principles of quantitative analysis. The principles and calculations of gravimetric analysis, including an introduction to mineral separations as well as the analysis of soluble salts; the principles and calculations of volumetric analysis,

including neutralization methods, oxidation-reduction methods, and iodometric methods. Offered both semesters.

CH 290 — Introduction to Chemical Engineering — (3-3)4
[CH 211]

An introductory study of the principles of material and energy balance, equilibrium, and rate of reaction. Examples are studied in the laboratory. The student is encouraged to develop his initiative and resourcefulness in obtaining experimental data, analyzing results, and communicating his findings by written and oral reports.

CH 302 — Introduction to Textile Chemistry — (1-3)2
[CH 102]

Lectures for the non-chemist on the various processes preliminary to dyeing. The preliminary treatments given the natural and manufactured fibers are studied as well as the action and properties of the textile chemicals used in these processes.

CH 307 — Atomic and Molecular Structure — (3-0)3
[CH 102]

Modern concepts of atomic and molecular structures as interpreted through emission, ultraviolet, infrared, and Raman spectra.

CH 311 Advanced Quantitative Analysis for Textile Chemists (2-4)3
[CH 211 or 212]

The examination and evaluation of chemicals utilized in the textile industry. Advanced techniques and instrumental methods are introduced for the analysis of bleaching agents, industrial water, soaps, oils, and synthetic detergents. Group projects and report writing. For students in the Textile Chemistry course.

CH 314 — Advanced Quantitative Analysis — (2-4)3
[CH 211 or 212]

Advanced principles and techniques of analytical separations with laboratory emphasis on some instrumental methods. The following topics will be considered: fractional precipitation methods, colorimetry, chromatography, compleximetry, potentiometric titrations, polarography, and organic precipitating agents. Group projects and report writing. For students in the Chemistry course.

CH 331-332 — Physical Chemsitry — Eng. Phys. (3-1½)(3-3)8
Others (3-3)(3-3)8

[CH 102, MA 205, PH 205]

The formulation and development of the mathematical and mechanical models of theoretical chemistry and their uses in the

solution of the practical problems of chemistry and chemical engineering. Topics included are atomic and molecular structure, states of matter, thermodynamics, thermochemistry solutions, electrochemistry, colloids, chemical equilibrium, kinetics, and photochemistry. CH 331 is for students not majoring in chemistry.

CH 333 — Industrial Stoichiometry — (3-0)3
[CH 211 or 212, PH 205]

A study of some important operations in the chemical industry, e.g., sulfuric acid, and in the pulp and paper industry from the standpoint of the application of reaction rate and mass and energy balance to the prediction of performance, yield, etc. Recirculatory processes are also studied.

CH 334 — General Colloid Chemistry — (3-0)3
[CH 331]

The approach is from the standpoint of the theoretical properties of the colloid system. Interfacial phenomena, particle kinetics, electrical properties, and viscosity characteristics are studied. The preparation of colloid solutions and the character of lyophobic and lyophilic sols, gels and emulsions are developed from the above fundamental properties.

CH 342 — Organic Qualitative Analysis — (1-6)3
[CH 202; CH 205 or 206]

Methods of identification of "unknown" organic substances whose properties have been previously published in the chemical literature.

CH 352 — Chemical Engineering — (3-0)3
[CH 102, CH 331, MA 206, PH 206]

Descriptive and quantitative information on unit conversion, dimensional analysis, materials of construction, flow of fluids, flow of heat, hygrometry, humidification, dehumidification, and drying.

CH 355 — Chemistry and Physics of Fibers — (2-3)3
[CH 202 and 211]

The structure and chemical reactions of linear high polymers of importance in the field of natural and synthetic fibers; the chemical and physical structure of polymers and fibers; the relation of molecular length, orientation, crystallinity, intermolecular attractions, side chains, and flexibility of polymers to the physical properties of fibers; chemical reactions of polymers and their effects on fibers.

CH 356 — Chemistry of Fiber Purification — (2-3)3
[CH 202 and 211]

A study of the impurities present in textile fibers and fabrics and their removal. Both natural and manufactured fibers are taken up. This subject is covered by lecture, laboratory and pilot plant work.

CH 364 — Textile Colloid Chemistry — (4-0)4
[CH 331]

Basic principles of surface and colloidal chemistry and their applications in industry. Special emphasis is placed on applications to the textile field: wetting, detergency, and finishing processes, as well as the colloidal behavior of the fibers themselves.

CH 401 — Introduction to Textile Chemistry — (1-3)2
[CH 302]

A continuation of CH 302. The application of various classes of dyes to natural and manufactured fibers. Methods of dyeing, fastness properties of different classes of dyes, and the nature and use of dyeing assistants are stressed.

CH 403-404 — Chemistry of High Polymers — (3-3)(3-3)8
[CH 202 and 332]

Definition and classification of high polymers; chemistry of the more important polymers including preparation, physical properties, and chemical properties; mechanism and procedures for polymerization, copolymerization, and condensation; physico-chemical investigations including molecular weight determination and distribution; the structure of high polymers including relationship of structure to properties; inter- and intra-molecular forces; states of aggregation; transition points; elasticity; visco-elastic behavior; cross-linking; plasticization (internal and external); solvent action.

CH 408 and/or 409 — Advanced Studies in Chemistry — Credits to be arranged

[Permission of the Chairman of the Chemistry Division and the instructor]

Advanced work in analytical, organic, inorganic, physical, or textile chemistry. Includes literature survey, laboratory work, and reports.

CH 422 **Chemical Textile Testing** (2-3)3

[CH 356 and 364]

Chemical methods of textile testing. Quantitative as well as qualitative determination of fiber content, finishing agents and dyestuffs. Includes optical methods of analysis and evaluation.

CH 423-424 **Advanced Organic Chemistry** (3-0)(3-0)6

[CH 202]

Extension of first-year organic chemistry to include additional classes of compounds and special topics. Emphasis is placed on synthetic methods including the mechanism, scope, and limitations of the important name reactions in the field of synthetic organic chemistry.

CH 425 **Organic Chemistry of Colored Substances** (2-0)2

[CH 201]

The relation between the structure of an organic molecule or ion and its absorption in the ultraviolet or visible spectral region. The synthesis and reactions of selected colored organic substances.

CH 431-432 **Advanced Physical Chemistry** (3-0)(3-0)6

[CH 314 and 332]

Extension of introductory physical chemistry for majors in chemistry and related fields. Includes additional work in chemical thermodynamics, kinetics, chemical statistics, photochemistry, etc., with emphasis on the use of the chemical literature, methods of treatment of data and problem solving.

CH 441 **Chemical Engineering** (3-0)3

[CH 352]

A continuation of CH 352. The unit operations of evaporation. gas absorption, filtration, and washing.

CH 442 **Chemical Engineering Thermodynamics** (3-0)3

[CH 332]

A study of the first law of thermodynamics. Heat capacity, perfect gases, phase rule, and generalized pressure, volume, and temperature relations. An introduction to the second law.

CH 443-444 **Advanced Inorganic Chemistry** (3-0)(3-0)6
[CH 202 and 314]
Graduate credit allowed

Advanced chemistry of the common elements and their compounds, including coordination complexes, inorganic stereoisomerism, ion exchange, etc.

CH 446 **Advanced Inorganic Chemistry Laboratory** (0-3)1
[CH 202 and 314]
Not offered in 1958-59

Inorganic preparations and advanced techniques.

CH 453 **Theory of Dyeing** (3-4)4
[CH 355 and 364]

Mechanisms of reactions in the dyeing of cellulose, cellulose acetate, protein, polyamide, polyester, and polyacrylonitrile fibers. Emphasizes basic physical and chemical variables affecting equilibria and rates of dyeing, diffusion and adsorption. In the laboratory, principles of transmission and reflectance spectrophotometric measurement are employed in kinetic and equilibrium studies.

CH 454 **Industrial Dyeing and Printing** (2-8)4
[CH 453]

A study of the technology of dyeing and printing the commercially important natural and synthetic fibers using the principle classes of dyes. Includes methods of application, color and color matching, dyestuff properties, and economics of dyeing processes. Principles of design and use of important industrial units are illustrated by pilot plant experiments. Engineering aspects of circulation, agitating, and heat exchange are considered, and the effect of these variables in the dyeing of printing processes is illustrated.

CH 461 **Microbiology** (1-3)2
[CH 202]

This subject considers the fundamentals of mycological and bacteriological theory briefly but in sufficient detail so that the problem of the microbiological deterioration of textiles, paper, and leather may be discussed. Methods of detecting mildewing, methods of testing textiles for mildew resistance, and bacteriological water analysis are also studied.

CH 464 **Advanced Microbiology** (1-3)2
[CH 461]

Work is arranged according to the particular interests of the student and consists of special projects.

CH 473 or 474 **General Biochemistry** **(2-4)4**
[CH 201-202 or permission of instructor]
Not offered in 1958-59 but available in 1959 Summer Session

The chemistry and metabolism of carbohydrates, proteins, and fats, and their products.

CH 475 or 476 **General Bacteriology** **(2-4)4**
[CH 201-202 or permission of instructor]
Not offered in 1958-59 but available in 1959 Summer Session

The fundamentals of bacteriology, covering the morphology, physiology, and pure culture characteristics of bacteria.

CH 481 **Nuclear Chemistry and Radiochemistry** **(1-3)2**
[CH 332]

The theory and practice of nuclear chemistry and radiochemistry.

CH 491 **Textile Chemistry Literature Seminar** **(2-0)2**
[Permission of instructor]

A study and discussion of current textile chemistry literature, stressing the critical analysis of the subject matter.

CH 501 **Color Measurement** **(1-3)2**
[CH 422 or equivalent]

Theory and application of adsorption spectrophotometry to the qualitative and quantitative analyses of colored substances in both transparent and opaque media in the ultraviolet, visible and near infrared ranges. Includes theories of color, vision, and subjective color evaluation.

CH 503 **Interpretation of Data** **(2-0)2**

Mathematical methods of analyzing, plotting, and interpreting experimental data. Lectures and exercises.

CH 505 **Physical Chemistry of Dyeing** **(2-3)3**

A combination of lectures, seminars, and laboratory experiments on the physicochemical principles involved in the application of dyestuffs to textile materials.

CH 507-508 **Chemistry Seminar** **(1-0)(1-0)2**

CH 512 **The Physical Chemistry of Surface-active Agents** **(1-3)2**
[CH 364]

A series of lectures and laboratory experiments on the physicochemical principles involved in the use of surface-active agents

in textile processing. The surface and bulk properties of the agents are studied and related to the over-all technical properties and uses.

CH 513-514 Physicochemical Methods (2-4)(2-4)6

Theory, applications, and limitations of important physical methods of analysis used in modern research. Methods will include X-ray diffraction, ultraviolet and infrared spectroscopy, and microscopy (phase, polarization, electron). Special attention is given to methods for determining the size and shape of macromolecules.

CH 521-522 Physical Organic Chemistry (3-0)(3-0)6

Treatment at an advanced level of the mechanisms of organic reactions and of the effects of changing structures and other variables on reactivity.

CH 523-524 Organic Chemistry of Polymeric Species (3-0)(3-0)6
[CH 202, 332, 424]

The classification, mechanism of formation, structure, and properties in bulk of polymeric organic species.

CH 525-526 Chemistry of the Carbohydrates (3-0)(3-0)6
[CH 202 and 332]

Starting with the chemistry of the simple sugars, this subject leads to a detailed study of the physical chemistry and the organic chemistry of the important polysaccharides, such as cellulose and starch, and of their industrially important derivatives.

CH 527 Metal-Organic Compounds (3-0)3

The chemistry of the important classes of metal-organic compounds including bis-arene derivatives. Includes in addition the organo-silicon, organo-boron, and organo-phosphorus classes.

CH 528 Stereochemistry (3-0)3

Concerns the fundamental concepts of optical and geometrical isomerism and the relationship of the stereo-structures to the physical and chemical properties of organic compounds.

CH 529 Heterocyclic Chemistry (3-0)3

Classification, nomenclature, structure, synthesis, and utility of the more important classes of heterocyclic compounds.

CH 531-532 Chemical Thermodynamics and Kinetics (3-0)(3-0)6

Classical and statistical principles of thermodynamics and their application to chemical problems. The description of system states

and the development of criteria for determining the spontaneity of physical and chemical changes are emphasized. Chemical kinetics includes order of reactions, factors influencing rates, and application of rate studies in establishing hypotheses for reaction mechanisms.

CH 533 Statistical Mechanics for Chemists (3-0)3

Mathematical introduction to statistical mechanics and the applications to chemical problems.

CH 534 Quantum Mechanics for Chemists (3-0)3

Application of the principles of quantum mechanics to chemical problems.

CH 535-536 Advanced Topics in Physical Chemistry (3-0)(3-0)6

Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

CH 538 Rheology (2-3)3

The general principles of the deformation and flow of matter under stresses are studied qualitatively and quantitatively. Hookean and non-Hookean elasticity and Newtonian and non-Newtonian flow are related to the properties of materials, especially in the field of high polymers. Special emphasis is given to the rheological properties of solutions and suspensions.

CH 541-542 Graduate Thesis Credits to be arranged

The graduate thesis is to be an independent investigation of a problem by the student in conference with a faculty adviser and approved by the Department Head. A clear and systematic written presentation of the results is a required part of this subject.

CH 551 or 552 Textile Testing Problems (1-3)2
[CH 422]

Special problems relating to the design and evaluation of improved analytical or testing procedures.

CH 553-554 Evaluation of Finishing Agents Credits to be arranged

A laboratory study designed to teach the use of the various test methods and instruments in evaluating the effect of finishing treatments on the tactile and end-use properties of a fabric.

CH 555-556 Textile Chemistry Seminar (2-0)(2-0)4

A series of informal discussions of current problems in research and technology in the textile chemistry field. Special investigations

of the literature will be utilized to serve as a source of seminar topics.

CH 559 Instrumental Methods in Textile Research (1-2)2

The use of instruments in textile chemical research. The lectures cover the general principles of instrumentation in the various fields considered. The laboratory exercises invoke the use of specific instruments and are designed to teach the student to make a proper choice of instrumental methods in common textile chemical problems.

CH 561-562 Polymer-Chemical Principles in the Technology of Organic Construction Materials (3-0)(3-0)6

Application of polymer-chemical principles to the chemical technology of organic construction materials (orcons) such as textiles, plastics, paper, and leather. For example, it is shown how the principle of cross-linking is utilized to modify the performance properties of cotton and rayon (crease recovery), of wool (permanent pleating), rubber (vulcanization), textile finishes and plastics (curing), leather (tanning) and paper (wet strength), and how the principle of swelling is utilized to make these materials accessible to modifying agents as in finishing, dyeing, and plasticization.

CH 563-564 Special Topics in the Chemistry and Technology of Manufactured Fibers (2-0)(2-0)4
[CH 355]

Important considerations in the areas of synthesis and structure of fiber-forming polymers, conversion of polymers into fiber forms, and fiber properties and applications.

ELECTRONICS

EL 201-202 Introductory Circuit Theory (4-0)(4-0)8

[PH 104 and MA 108; EL 205-206 and 207-208 taken concurrently]

An introduction to the study of the mathematical and physical aspects of electric circuits in which radiation in the form of electromagnetic waves does not play a major role. Resistive circuits, Kirchhoff's laws, Thevenin's theorem, reciprocity of simple circuits, sinusoidal steady-state behavior, vector diagrams, resonance, transients in alternating current circuits, loci of complex functions, polyphase systems, and an introductory discussion of simple nonlinear circuits.

Text: Guillemin, *Introductory Circuit Theory.*

EL 203-204 Elementary Electricity and Magnetism Laboratory (0-3)(0-3)2

[PH 104; EL 201-202 taken concurrently]

The purpose of this subject is to give the student a working knowledge of the use of common electrical devices and measuring equipment as well as practice in the preparation of circuit drawings, the writing of technical reports, and the analysis of the precision of measurements. Some attention will be given to the practical techniques useful in the construction of electrical equipment and accessories. Among the topics considered in the laboratory are: measurements of resistance, capacitance, inductance and impedance; d.c. and a.c. bridge circuits; magnetic measurements; characteristics of vacuum tubes and other nonlinear devices; elementary vacuum tube circuits; a.c. and d.c. motors, and transformers.

Texts: Stout, *Basic Electrical Measurements;* Dunn and Barker, *Electrical Measurements Manual.*

EL 205-206 Introductory Field Theory (4-0)(4-0)8

[PH 104 and MA 108; EL 207-208 taken concurrently]

The fundamental laws of electricity and magnetism presented from the point of view of field theory. Free use is made of the calculus. Topics in the first semester include electrostatics, steady currents and their magnetic fields, induced electromotive forces and inductance, elementary alternating current circuits, and time-dependent magnetic fields. In the second semester the following topics are studied: electromagnetic waves in free space, on wires,

and in material bodies; behavior of electrons in metals, thermionic emission, dielectric and magnetic properties of matter, geometrical optics, physical optics, atomic structures, and topics in modern physics.

Text: Frank, *Introduction to Electricity and Optics*, 2nd edition.

EL 207 — Intermediate Engineering Mathematics — (4-0)4

[MA 108]

A continuation of MA 108. Methods of integration, elementary vector analysis, elements of solid analytic geometry, partial differentiation, multiple integrals, infinite series, and the elements of complex variable theory. Stress is given to the application of the mathematics to problems in applied science and engineering.

Text: Thomas, *Calculus and Analytic Geometry.*

EL 208 — Differential Equations for Engineers — (4-0)4

[EL 207]

A general survey of ordinary differential equations and an introduction to partial differential equations and the Laplace transformation. Numerous applications are made to problems in physics, chemistry and geometry.

Texts: Reddick and Kibbey, *Differential Equations* (3rd edition); Jaeger, *Laplace Transformation;* Peirce, *A Short Table of Integrals.*

EL 301 — Introduction to Physical Electronics — (3-0)3

[EL 202 and 208]

The motion of charged particles in electric and magnetic fields, electronic phenomena in metals, statistical electron theory of metals, characteristics of thermionic cathodes, kinetic theory of gases, fundamental processes in gases, electrical discharges in gases, rectifiers and filters, photoelectricity, diodes, gas tubes, photoelectric cells, triodes, and multielectrode tubes.

Texts: Millman and Seely, *Electronics;* Van Name, *Modern Physics.*

EL 303-304 — Electronic Circuits — (3-0)(3-0)6

[EL 202 and 208; EL 301 taken concurrently]

Characteristics of electronic tubes; graphical solutions for circuits containing nonlinear elements; linear equivalent circuits; combinations of resistive, capacitive, and inductive elements; response of basic circuits to simple wave forms; amplifiers; oscillators;

clamping, clipping, and trigger circuits; voltage-regulating circuits; multivibrators; and counting circuits.

Texts: Corcoran and Price, *Electronics;* Martin, *Electronic Circuits.*

EL 305-306 Electronics Laboratory (0-4)(0-4)4
[EL 202, 204, and 206; EL 303-304 taken concurrently]

The purpose of this subject is to give the student a good working knowledge of a number of electronic circuits and the techniques of measurement for evaluating their performance. A number of these circuits are assembled by the student. Further training is provided in the analysis and reporting of experimental work. Development of the student's initiative, resourcefulness, and independent judgment is encouraged.

Text: Reed, Wagner and Corcoran, *Electrical Communications Experiments.*

EL 307-308 Electromagnetic Devices and Machinery (3-0)(3-0)6
[EL 202, 206, and 208; EL 311-312 taken concurrently]

Dimensional analysis, free and forced response of dynamic systems, electromechanical analogies; electromagnetic, piezoelectric, magnetostrictive, electrothermal, and electromechanical devices; indicating and recording equipment, electrical computers, and fractional horsepower motors.

EL 310 Electromagnetics (3-0)3
[EL 202, 206, 208, and 311; EL 312 taken concurrently]

Electricity and magnetism are presented from the field theory point of view. Vector analysis is used throughout and Maxwell's equations are introduced early in the course. The topics covered include the static electric field in polarizable and conducting media, static magnetic fields of steady electric currents and ferromagnetic materials, time-changing electric and magnetic fields, magnetic induction, and boundary value problems associated with static fields.

Text: Kraus, *Electromagnetics.*

EL 311-312 Engineering Mathematics (4-0)(4-0)8
[EL 208]

Ordinary differential equations, Laplace transformation, numerical methods of solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations, partial

differential equations of mathematical physics, and complex variable theory.

Text: Hildebrand, *Advanced Calculus for Engineers.*

EL 401-402 Servomechanisms (3-0)(3-0)6
[EL 304 and 312]

A survey of industrial electronic control systems. Among the topics considered are: selsyns, amplidynes, regulators, servomechanisms, magnetic amplifiers, saturable reactors, inverters, high-current rectifiers, and high-voltage machines.

Texts: Brown and Campbell, *Principles of Servomechanisms;* Thaler, *Elements of Servomechanism Theory.*

EL 403-404 Microwave Electronics (3-0)(3-0)6
[EL 304 and 312]

Practice in the analysis of electronic systems. Beginning with zero frequency circuits, a study is made of the modifications required to give proper behavior as the frequency is increased. Among the topics considered are: radio frequency circuits; television circuits; amplitude, frequency, and pulse modulation; elements of electromagnetic theory, antennas, waveguides, microwave generators and receivers.

Texts: Reich *et al., Microwave Theory and Techniques;* Reintjes and Coate, *Principles of Radar;* Panofsky and Phillips, *Classical Electricity and Magnetism.*

EL 409-410 Electronic Projects Laboratory (0-4)(0-4)4
[EL 306 and 310]

In this subject the student is given the opportunity to develop, construct, study, modify, and test electronic components and systems. He is expected to carry out his investigations more or less independently. Original investigations are encouraged but not required. The careful preparation of technical reports on the experimental work is emphasized. Where practicable, the student is expected to write his reports using the style of either the *Journal of the Institute of Radio Engineers* or the *Review of Scientific Instruments.*

EL 411-412 Applied Electronics Laboratory (0-4)(0-4)4
[EL 306 and 310]

The purpose of this subject is to give the student an experimental familiarity with the nature, application, and performance of various electronic devices. Emphasis is given to the preparation of good technical reports.

Text: Terman and Petit, *Electronic Measurements.*

EL 413-414 Thermodynamics and Properties of Materials (3-0)(3-0)6
[EL 301, 310, and 312]

The fundamental concepts of thermodynamics and statistical mechanics with emphasis on applications to the solid state.

EL 415-416 Communications Theory (3-0)(3-0)6
[EL 304]

Theory and applications of thermionic tubes and transistors in amplifiers, oscillators, modulators, and detectors. Principles of television communication.

Texts: Martin, *Electronic Circuits;* Everitt and Anner, *Communication Engineering.*

EL 417-418 Network Analysis (3-0)(3-0)6
[EL 304]

The formulation of general network equations and the development of various equivalent circuits and circuit theorems. The transient behavior of linear networks, characteristics of wave filters, circuits having continuously distributed constants, and other coupling networks.

Text: Van Valkenburg, *Network Analysis.*

EL 419 Basic Principles of Computers (3-0)3
[EL 304 and 306]

Instrumentation principles of analog and digital computers, electromechanical analogies as used for electrical analog computers, basic design of digital computers, and applications of computers to problems in science and engineering.

EL 420 Instrumentation (3-0)3
[EL 304 and 306]

Methods of electrical measurement of physical quantities such as temperature, pressure, velocity, acceleration, radiant energy, ionization, and noise.

EL 425-426 Special Topics in Electronics (3-0)(3-0)6

An analytical consideration of special topics of importance in the field of electronics.

EL 501-502 Mathematical Methods for Engineers (3-0)(3-0)6

Elements of function theory, differentiation, integration, space geometry, functions of a complex variable, residues and complex

integration, and applications. Algebra of linear equations, vector and tensor analysis, orthonormal functions, integral equations, and variational methods.

Texts: Smith, *Mathematical Methods for Scientists and Engineers;* Page, *Physical Mathematics.*

EL 503-504 Introduction to Theoretical Physics (3-0)(3-0)6

The student is introduced to the analytical methods of theoretical physics. The major emphasis is placed on prequantum physics. The following topics are covered: the Lagrangian and Hamiltonian formulations of analytical mechanics; special relativity; elasticity and hydrodynamics, kinetic theory, thermodynamics, and statistical mechanics; electricity and magnetism from the field-variable point of view; Maxwell's equations; and atomic spectra and structure.

EL 505-506 Microwave Electronics (3-0)(3-0)6

Elements of electromagnetic theory, transmission lines, impedance matching, waveguides, antennas, microwave oscillators and amplifiers, klystrons, magnetrons, and travelling wave tubes.

Texts: Reich *et al., Microwave Theory and Techniques;* Reintjes and Coate, *Principles of Radar;* Panofsky and Phillips, *Classical Electricity and Magnetism.*

EL 507-508 Intermediate Solid State Electronics (3-0)(3-0)6

An intensive study of selected topics in solid state electronics.

Texts: Shockley, *Electrons and Holes in Semiconductors;* Slater, *Quantum Theory of Matter;* Peierls, *Quantum Theory of Solids.*

EL 509-510 Transients in Electromechanical Systems (3-0)(3-0)6

Training in the formulation and solution of ordinary and partial differential equations which arise in the treatment of mechanical, acoustical, thermal, and electrical systems. Extensive use is made of modern operational mathematical techniques.

Text: Gardner and Barnes, *Transients in Linear Systems.*

EL 511-512 Dynamic Control Analysis (3-0)(3-0)6

The basic principles of electronic devices used for control and measurement in applied science and engineering.

Text: Truxal, *Automatic Feedback Control System Synthesis.*

EL 513-514 Electromagnetic Theory (3-0)(3-0)6

Maxwell's equations, stress and energy, the electrostatic field,

the magnetostatic field, plane waves in isotropic media, cylindrical waves, spherical waves, radiation, and boundary value problems.

Text: Stratton, *Electromagnetic Theory.*

EL 515-516 Elementary Quantum Mechanics (3-0)(3-0)6

The postulational formulation of quantum mechanics. The basic theory is developed both in the operator and matrix formulations.

Texts: Schiff, *Quantum Mechanics;* Persico, *Fundamentals of Quantum Mechanics.*

EL 517-518 Solid State and Modern Physics for Engineers (3-0)(3-0)6

Elements of electronics, special theory of relativity, atomic structure of matter, quantum mechanics, X-rays, molecular structure and molecular spectra, low-temperature phenomena, natural and induced radioactivity, nuclear fission, cosmic rays and mesons, elements of crystal physics, specific heats, alloys of metals, elastic and plastic properties of solids, rupture and fatigue of solids, thermal diffusion, electron theory of metals and alloys, thermal and electrical properties of solids, energy levels in solids, cohesion in solids; magnetic, paramagnetic, and diamagnetic properties of solids; magnetic moments and resonance, transistor physics, semiconductors, and electron diffusion in metals.

Texts: Kittel, *Solid State Physics;* Slater, *Quantum Theory of Matter;* Peierls, *Quantum Theory of Solids.*

EL 519-520 Seminar in Electronics (1-0)(1-0)2

Discussion by staff members and students of current journal publications and topics of current interest in electronic science, electronic engineering, and related areas of applied physics.

EL 521-522 Special Problems in Electronics

The purpose of this subject is to give the student an opportunity for individual study, under the direction of a staff member, of topics in or related to electronic engineering.

EL 525-526 Graduate Research

Supervised research on some problem in electronic science, electronic engineering, or in certain areas of applied physics. The results of the research are to be embodied in a thesis acceptable to the departmental committee on graduate study.

ENGINEERING

EN 113 **Engineering Graphics** **(0-3)1**

Freehand and instrumental multiview drawing, fundamentals of dimensioning, engineering geometry, isometric sketching, charts and graphs.

EN 114 **Engineering Graphics** **(0-3)1**
[EN 113]

Auxiliary views, sectional views, basic descriptive geometry, intersections and developments, fasteners, dimensioning.

EN 201 **Machine Drawing** **(0-3)1**
[EN 114]

Several short problems involving centers of gravity, cam layouts, counterweights, welding, limit dimensioning, and graphical calculus.

EN 203 or 204 **Mechanism** **(3-0)3**

The basic principles of kinematics, in which the wide variety of process machinery available furnishes many specific examples. Frequent use of these mechanisms is made in the development of the subject. Some of the important topics covered are the following: rolling cylinders and cones, gearing, gear train design, epicyclic gear trains, flexible connectors including stepped pulley and cone design, cam design, linkages, and miscellaneous mechanisms.

EN 205 **Mechanism** **(3-2)4**

Similar to EN 203, except that laboratory time has been provided to allow study of textile mechanisms.

EN 207 **Machine Drawing** **(0-6)2**
[EN 114]

Short problems involving centers of gravity, cam layouts, counterweights, piping diagrams, welding, assembly drawings, limit dimensioning and tolerances, and graphical calculus.

EN 211 or 212 **Machine Tool Laboratory** **(1-2)1**

The objective of this subject is to give the student an insight into the processing of metals through lectures and practical labora-

tory applications covering the basic machine tools such as the lathe, shaper, drill-press, and milling machine, and also the uses of measuring instruments, threads, and gears. Lectures and demonstrations cover topics such as pattern work, foundry practice, die-casting, welding, and forging.

EN 222 or 223 — Applied Mechanics I — (3-0)3
[MA 108, PH 103]

The fundamentals of statics including such topics as force systems, laws of equilibrium, centers of gravity, moments of inertia, and analysis of stresses in framed structures.

EN 232 — Engineering Materials — (3-0)3
[PH 103]

The manufacture, properties, and uses of important ferrous and nonferrous metals; hot and cold processing, alloying, heat treatment; also the properties and use of nonmetallic engineering materials such as timber, cement, concrete, rubber, plastic, and mechanical fabrics.

EN 234 — Plastics Mold Design and Construction — (1-2)1
[EN 211 or 212]

The purpose of this course is to acquaint plastics engineering students with the basic principles of mold design and construction in addition to machining and finishing operations of plastics. Sufficient laboratory time is provided to allow for the design and construction of simple molds.

EN 301 — Applied Mechanics II — (3-0)3
[EN 222, MA 206]

The principles of rectilinear and curvilinear translation, rotation and plane motion; Newton's laws, D'Alembert's principle. Work and energy, impulse and momentum, mechanical vibrations.

EN 302 — Applied Mechanics III — (3-0)3
[EN 222, MA 206]

Stress, strain, Hooke's law. Shearing stress, riveted and welded connections. Combined stresses, Mohr's circle. Shearing force and bending moment. Beam stresses, normal bending, deflections. Simple torsion, column theory.

EN 303 — Electrical Circuits — (3-2)3
[MA 206, PH 205]

Ohm's law and Kirchhoff's laws, direct current networks, Thevenin's theorem, impedance, representation of alternating

quantities by vectors, sinusoidal steady-state properties, power, series and parallel resonance, polyphase systems, network theorems for steady-state alternating current circuits, coupling networks, transients in simple circuits, Fourier series.

EN 304 Instrumentation for Textile Processing (2-2)3
[PH 104 and 205]

A study of indicating and recording instruments used to measure such common textile process variables as pressure, temperature, humidity, liquid level, fluid flow, etc. An introduction also to electronic circuitry as it relates to textile processing instrumentation controls.

EN 305 Thermodynamics (3-0)3
[MA 205, PH 104]

The thermodynamic system, the first law of thermodynamics, internal energy. Open and closed systems, steady flow, reversibility. The second law of thermodynamics, entropy, availability. The pure substance, the perfect gas; mixtures of gases and vapors.

EN 307 Surveying and Structures (3-3)4
[EN 222]

The fundamental principles of plane surveying, topographic surveying and mapping, principles of structural engineering, algebraic and graphical analysis of forces, calculation of allowable floor loads, stresses in beam and allowable loads on columns.

EN 308 Structures (3-0)3
[EN 307]

Rigid frames analysis, wind stresses, stresses in riveted trusses, reinforced concrete structures, footings, foundations.

EN 309 Metals Processing (2-2)3
[EN 211 or 212]

Modern methods of manufacture including casting, forging, metal cutting and turning, spinning, welding. Testing for hardness, tensile strength, shrink fits, soldered and welded joints. Survey of current technical literature and special topic assignments.

EN 311 Heat and Power (2-2)3
[PH 205]

Similar to EN 403 but briefer and designed for those not majoring in engineering.

EN 313 or 314 — **Advanced Mechanism** — (2-2)3

[EN 203]

The graphical and mathematical analyses of advanced mechanisms found in various machines. The forces in, and velocities of, the various members of the mechanism are determined from actual data taken from the machines by the student. The subject is terminated with a problem in the design of a mechanism.

EN 316 — **Heat Engineering** — (3-3)4

[EN 305]

Applications of the basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A treatment of steam-generating units, turbines, and pumps.

EN 325 or 326 — **Applied Mechanics** — (3-0)3

[MA 108, PH 103]

The fundamentals of statics, including such topics as force systems, laws of equilibrium, friction, centers of gravity, moments of inertia, and an introduction to dynamics.

EN 328 — **Strength of Materials** — (3-0)3

[EN 325]

Principles of the strength of materials with special emphasis on their applications to plastics. Includes such topics as bending and shearing stresses, torsion, compound beams and columns, reversals of stress, impact, vibrations, stress analysis by strain gage methods, concepts of creep and relaxation.

EN 331 or 332 — **Strength of Materials** — (3-0)3

[EN 222 or 325]

This subject covers such topics as stress fundamentals, strain bending moment and deflection, beam design, torsion, columns, combined stresses, reversals of stress, and impact.

EN 342 — **Principles of Electrical Engineering** — (3-2)4

[PH 321]

The greater part of the subject is devoted to direct-current generators and motors with a study of their construction and characteristics. Three-phase circuits and alternators are also considered. The accompanying laboratory work illustrates the various methods of measuring polyphase power and of determining the characteristics of direct-current generators and motors.

EN 344 **Electrical Machinery** **(3-2)4**

[PH 321]

A condensation of EN 342 and EN 401.

EN 351 or 352 **Statistical Methods** **(3-0)3**

[MA 108]

The application of modern statistical techniques to the treatment of experimental data. Characteristics of distributions, significant differences, linear correlation, and analysis of variance. Introduction to the planning of industrial experiments.

EN 401 **Principles of Electrical Engineering** **(3-2)4**

[EN 342 or PH 322]

Alternator regulation, parallel operation, single-phase and three-phase transformers, induction motors and their applications to the textile industry, starting devices for motors, synchronous motors, and correction of power factor.

EN 402 **Electrical Control Systems** **(3-2)4**

[EN 401]

Not offered in 1958-59

The operation of simple servomechanisms, potentiometers, synchros and related error detectors, double-speed synchronizing networks, demodulators and modulators, electronic amplifiers, servomotors, magnetic and rotating amplifiers, design of servomechanisms, tests of servomechanisms.

EN 403 **Principles of Heat Engineering** **(3-2)4**

[MA 205, PH 104]

The basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A brief treatment of steam engines, turbines and pumps. Special consideration is given to the use of steam in manufacturing processes.

EN 404 **Heat Transfer** **(3-0)3**

[MA 205, PH 104]

Modes of heat transfer; conduction, radiation, forced and free convection. Dimensional analysis. Heat transfer to boiling liquids and condensing vapors. Over-all transfer of heat. Finned surfaces and heat exchangers. Transient conduction.

EN 405 Electronic Controls and Power Circuits (3-2)4
[PH 205]

Power requirements in single-phase and three-phase power circuits; operating characteristics of various types of direct-current and alternating-current motors and their manual and automatic controls; industrial electronics including photoelectric relays, time delay relays, motor control, and side register control as applied in the plastics industry.

EN 406 Fluid Mechanics (3-2)4
[MA 205, PH 205]

Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs; orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids; Mach's number; dynamical similitude and Pi theorem.

EN 407 or 408 Fluid Mechanics (3-0)3
[MA 205, PH 205]

Similiar to EN 406 but without laboratory work.

EN 411 or 412 Advanced Heat Engineering (3-2)4
[EN 316]

Elements of the design of power plants and heating systems, internal combustion engines, and related subjects.

EN 420 Industrial Instrumentation (2-3)3
[PH 205]

Similar to EN 422 with the addition of three hours of laboratory per week.

EN 422 Industrial Instrumentation (2-0)2
[PH 205]

Modern methods of measurement and control of the more common process variables such as temperature, pressure, liquid level, and fluid flow; response characteristics of mechanical, electric and electronic instruments; modes of control; associated mechanical and electrical mechanisms; characteristics of final control elements; closed-loop control systems; process characteristics and their effects upon the selection of the correct mode of control.

EN 427-428 **Machine Design** (2-3)(2-3)6
[EN 302]

The application of engineering principles to the design of machine elements including working stresses, shafting, springs, screws, belts, clutches, brakes, lubrication, bearings, gearing, press and shrink fits, miscellaneous machine elements, and optimum design considerations.

EN 429-430 **Engineering Design of Textile Structures** (3-0)(3-0)6
[Permission of instructor]

This subject correlates engineering properties of textile materials, engineering principles, and textile processing in the design of textile structures with desired properties. The geometry of yarns and fabrics; design of textile structures for certain functional uses; prediction of dimensional changes which occur during use; stresses, strains, and energy changes which the end use imposes; analyses of load-elongation diagrams of textile structural material.

EN 431 or 432 **Advanced Physical Textile Testing** (2-3)3

Compression testing, engineering properties of fibers and yarns, stress-strain-time phenomena of viscoelastic materials, theory and operation of strain gage testing machines, methods of measurement of yarn evenness, thermal transmission, flexibility of fabrics, fabric friction, bursting stress, and crimp. Use of the microscope in determination of wool quality, filament area and number. Statistical analysis of data.

EN 433 **Manufacturing Tools and Methods** (3-0)3
Not offered in 1958-59

Designed to familiarize students with manufacturing methods and machines in general industrial work. Plant layout and planning; machine tool performance; power transmission and control; product evaluation and quality control.

EN 441 or 442 **Air Conditioning** (2-2)2
[PH 205]

The fundamental principles of heating, ventilating, and refrigeration. The laboratory consists of design problems in the air conditioning of industrial buildings.

EN 501 or 502 **Statistical Quality Control** (3-0)3
[EN 351 or 352]

A study of the various types of control charts for maintaining the quality of manufactured products and the several types of sam-

pling plans for the reduced inspection of manufactured products and of raw materials. Applications of the foregoing statistical techniques to industry in general are discussed, with special emphasis on their application to the textile and other industries.

EN 505 or 506 **Methods of Experimental Stress Analysis** (2-3)3
[EN 302, MA 205, PH 205]

An introduction to some of the experimental techniques used in stress analysis. Photoelasticity, electrical strain gages, brittle coating, and mechanical gages are considered in relation to the analysis of both static and dynamic stresses. Special attention is given to the application of these techniques in the study of textile structures and machinery.

EN 509 or 510 **Advanced Statistical Methods** (3-0)3
[EN 351 or 352]

A continuation of EN 351 or 352 with particular study of the more advanced statistical techniques as applied to the design of industrial experiments and to the analysis and interpretation of the resulting data.

EN 511-512 **Graduate Thesis** Credits to be arranged

Each graduate student in Textile Engineering is required to submit a thesis which shows ability and originality in the solution of a research project.

EN 513-514 **Graduate Seminar** (1-0)(1-0)2

Required of all graduate students in Textile Engineering.

GENERAL STUDIES

GS 101-102 World Economic Geography (2-0)(2-0)4

Through a study of this subject the student gains an appreciation of the economic status of the different geographic areas of the world. The effect of climate, the geographic structure, and the distribution of important raw materials upon the activities of the people inhabiting those areas and on the types of industry which support the economic life of the various regions.

GS 111 English Composition and Reading (3-0)3

Training in the basic principles of correct and clear expression. Concentration on paragraph construction and development leading to effective expository writing. Analysis and discussion of the composition and content of collateral reading. Regularly assigned written exercises and individual conferences.

GS 112 English Composition and Reading (3-0)3

Training in the composition of extended written exercises. Introduction to the elementary research techniques of outlining, note taking, footnoting, compiling bibliographies, and more intensive use of the library. Critical analysis and discussion of collateral reading in the sciences and humanities. Regular individual conferences.

GS 122 Perspective Drawing (1-1)1

A mechanical method of representing objects of three dimensions, showing correct proportions as they appear to the eye.

GS 132 Freehand Drawing (0-3)1

Freehand drawing of objects of different textures. Visual training and graphic expression to build a drawing vocabulary which will aid in advanced drawing subjects.

GS 201-202 Economics (3-0)(3-0)6

The principles and practices of economics and a brief study of economic history.

GS 205 or 206 Man and His Environment (3-0)3

The biological aspects of fundamental problems of heredity and environment which confront man in his economic, social, and cultural life. Emphasis is given particularly to the fields of ecology, genetics and eugenics, evolution, and anthropology.

GS 209 or 210 Speech (2-0)2
[GS 112]

The aim of this subject is to achieve effective delivery of various types of speech. All kinds of delivery are studied and analyzed.

GS 211 or 212 Business English (2-0)2
[GS 112]

Analysis and practice in letter writing and a study of the basic forms of technical exposition, forming a background for report writing in advanced courses and in industrial activity.

GS 213 Technical and Scientific Writing (3-0)3

Thorough grounding in the special demands of technical and scientific exposition, including reports, technical and business correspondence, and research papers, supplemented by readings in technical and scientific fields. Practice in oral communication in connection with the presentation of abstracts, summaries, and reports based on readings and on problems coordinated with the written requirements of other departments.

GS 214 Communication of Ideas (3-0)3

Study and interpretation of assigned readings in the several forms of nontechnical writing, such as the novel, short story, drama, essay, and poetry, with the purpose of familiarizing the student with the methods by which thought is communicated. Skill in presenting ideas is developed through written assignments, including essays or reports of an analytical or critical nature, through oral expression by panels and committees, and through individual oral presentation of assigned subjects.

GS 222 Appreciation of Literature (3-0)3
[GS 112]

The principles of literary appreciation and criticism. An analysis of prose and poetical selections, with directed investigation of the various literary appeals—the intellectual, the sensory, the emotional, the aesthetic, the imaginative, and the philosophical.

GS 223 or 224 The United States since 1865 (3-0)3

A survey of the advancement of the American people from the Reconstruction Era through World War II.

GS 226 World History since 1900 (3-0)3

Particular attention is paid to the years 1919-1939 and such topics as the rise of new states; the origin and development of new concepts of nationalism, racism, and other phenomena; the align-

ment of world powers for World War II; and the role of the United States in mid-twentieth-century reconstruction.

GS 232 Comparative Literature (3-0)3

A consideration of at least six classics of western civilization as keys to the development of literary types. An attempt to deduce standards of critical judgment. Class discussions and critical papers.

GS 234 Shakespeare (3-0)3

A study of Shakespeare's chief tragedies, comedies, and chronicles. Lectures and discussions on Shakespeare and the nature of man. Critical papers.

GS 261-262 Technical German (3-0)(3-0)6

The basic elements of German, leading to the development of reading ability in scientific German.

GS 263-264 Technical French (3-0)(3-0)6

The basic elements of French, leading to the development of reading ability in scientific French.

GS 301 Economic Development of the United States (3-0)3

A brief review of the background of the present economic system and an intensive study of the influence of science and technology upon our economic development. The central theme is the dominant role of the science and technology of our time in present-day American life.

GS 302 Modern Labor Problems (3-0)3

A study of the backgrounds of present-day labor organizations and modern labor law with particular emphasis upon current labor problems in the United States. The major objective of the semester is to familiarize upper-class students with the procedures and techniques of collective bargaining with special attention to the formulation and administration of various types of labor contracts.

GS 303 Psychology (3-0)3

The place of psychology in the life of the individual and society. Physiological bases of behavior and experience, attention, perception, memory, thinking, emotions, intelligence, and personality in terms of the whole person in his social setting.

GS 307 | Business Finance | (3-0)3

[GS 202]

The organization of private enterprise, partnership, and corporate forms of business enterprises. Emphasis is placed upon financing business according to short-term, intermediate, and long-term needs. Tax considerations for the various business forms are studied.

GS 308 | Money and Banking | (3-0)3

[GS 202]

The monetary and banking system in the United States. The role of the Federal Reserve and the Treasury in terms of monetary policy and fiscal management.

GS 311 | Economic Statistics | (3-0)3

Basic concepts of the statistical method with special emphasis on those approaches of most interest to the student of management. Topics covered include measures of central tendency, graphic methods, dispersion, skewness, sampling, normal curve, index numbers, correlation, time series, secular trend, seasonal variation, business cycle, and statistical forecasting.

GS 321 | Marketing Principles | (3-0)3

[GS 202]

Functions of marketing; the consumer; retail marketing structure; the wholesaler; marketing by manufacturers; price policy; fair trade; and the government and marketing. A prerequsite for all advanced marketing subjects.

GS 322 | Marketing Problems | (3-0)3

[GS 321]

Case material is used to expand the topics considered in GS 321. Appropriate cases in each area will be assigned, discussed, and occasionally written up.

GS 341 | Accounting I | (3-0)3

The significance of accounting, underlying theories, the organization and use of modern accounting records. The preparation of the balance sheet and profit and loss statement. Theory of debits and credits as applied to journalizing and usage of various ledgers and journals. Comparison of corporate, partnership and proprietorship forms of organization from the accounting standpoint.

GS 342 **Accounting II** (3-0)3

A continuation of GS 341 with emphasis on partnership and corporate accounting. Tax accounting; installment and branch accounting; interpretation and analysis of formal financial statements, and preparation of accounting reports. General study of cost accounting principles and applications.

GS 344 **Cost Accounting** (3-0)3
[GS 341]

A study of cost finding for manufactured goods. The necessity and principles of material control and accounting; direct labor accounting, overhead accounting, and distribution costing. Job order, process, and standard cost accounting systems are utilized.

GS 361-362 **Advanced Technical German** (3-0)(3-0)6
[GS 262 or equivalent]

GS 361 may be taken without continuing GS 362.

This subject is designed to expand the student's elementary understanding of the language, increase vocabulary, and develop reading aptitudes in special fields of interest selected by the student.

GS 371 or 372 **American Civilization—1763-1865** (3-0)3

The beginnings of a national consciousness viewed from the aspects of the cultural, economic, and social evolution of the American people. The way of life of a growing democracy—its methods of livelihood, its art, its religious activities, its industries, its literature.

GS 401 or 402 **Industrial Relations Seminar** (2-0)2
[Permission of instructor]

This subject gives a small, selected group opportunities to meet with the instructor and occasional visitors in discussion of current problems in industrial relations. Case material and hypothetical problems in modern labor management provide the basis for group study.

GS 411 or 412 **Industrial Management: Principles and Problems** (3-0)3

Backgrounds of modern industry, organization of the industrial enterprise, the operation of modern industry, and coordination of the productive processes. Among the topics covered are risks, forecasting, financing, product development, plant layout, production controls, personnel management, time and motion studies, job evaluation, and wage and salary administration. The

text material is supplemented with current readings and case material.

GS 442 International Trade (3-0)3

[GS 321 or permission of instructor]

The growth and development of international trade. The classical theory of international trade and modern developments. Practical aspects of import-export practice and export management.

GS 443 Advertising (3-0)3

[GS 321 or permission of instructor]

The basic principles of advertising and their application to the solution of advertising problems encountered by business executives. Some attention is devoted to advertising technique and the use of motivation research.

GS 444 Sales Management (3-0)3

[GS 321 or permission of instructor]

Sales management in its broader aspects. Sales organization, management of a sales force, compensation of salesmen, and the selection, training and supervision of salesmen. Market research, product packaging and development, and distribution policies are also considered.

GS 461 Personnel Management (3-0)3

A comprehensive study of modern labor management techniques in the recruiting, selection, training, and placement of members of the work force. Personnel administration agencies and procedures, with special attention to such matters as employee health and safety, welfare and recreation programs, wage and salary administration, training and education, and management relations with labor organizations.

GS 463 Business Law (3-0)3

The basic principles of commercial law including contracts, agency, sales, partnerships, corporation, negotiable instruments, bailments and carriers, insurance, personal property, real property, suretyship and guarantee, and bankruptcy.

GS 465 or 466 Management Problems Research (3-0)3

[Permission of instructor]

Normally restricted to seniors and graduate students. Under faculty guidance, a student studies a topic in the field of finance,

marketing, or production. The findings are presented in formal thesis form. These theses are retained by the Department for permanent reference.

GS 468 Investment Fundamentals (3-0)3
[GS 307]

Analyzes the nature of different types of corporate securities from the viewpoint of the individual investor. Emphasis is placed upon the significance of various analytical techniques involved in appraising the intrinsic merits of industrial securities. Investment policy problems of portfolio construction are considered.

GS 469 or 470 Comparative Modern Governments (3-0)3

A study of twentieth-century political thought and the structure and functions of government agencies in democratic and totalitarian political systems. Emphasis is given to new concepts of government authority and responsibility and to changing patterns of international relations.

GS 471 or 472 American Foreign Policy, 1774 to the Present (3-0)3

A study of the development of U. S. foreign policy from the beginnings of the Republic to our present position in world affairs. Particular attention is given to the influences of two world wars and their aftermaths upon American participation in global politics.

GS 473 Modern Drama (3-0)3

A survey of major forces in the theater from the time of Ibsen to the present. Selected representative plays of American and European dramatists are read and discussed.

GS 475 The Modern American Novel (3-0)3

A consideration of outstanding American novelists from 1920 to the present. Selected works of Faulkner, Fitzgerald, Hemingway, Wolfe, and others are read. Discussion of novels of war, satire, social protest, and "hard-boiled" realism.

LEATHER

LE 202 — **Applied Leather Analysis** — **(1-4)2**
[CH 102]

A subject designed to acquaint the student with the accepted methods of analysis of the American Leather Chemists Association and other supplementary procedures.

LE 301-302 — **Leather Technology** — **(3-6)(3-6)10**

Introduction to the technology of leather manufacture. The first semester is devoted to examining government regulations in imported hides and skins, studying the purchasing of hides and skins, and classifying various hide damages. This is followed by work on the handling of raw stock at the tannery, unhairing, bating, and hide classification. The second semester is concerned primarily with the study of vegetable tanning, chrome tanning, and various other types of tanning. In the work throughout the year the material covered in lectures is supplemented by laboratory studies on a small scale.

LE 303 — **Leather Histology** — **(2-4)4**
[CH 201-202]

A study of the structures of animal skin and of the changes which they undergo in the leather-making process. Because the basically extracellular nature of skin demands it, considerable time is devoted to the nature and function of the fundamental protein constituents.

LE 304 — **Leather Microbiology** — **(2-4)4**
[CH 202 or permission of instructor]

An introduction to the study of microbiology, with special emphasis placed upon the microorganisms which may be encountered on skins or in the tannery.

LE 401-402 — **Leather Technology** — **(3-6)(3-6)10**
[LE 302]

A continuation of the study into the technology of leather manufacture covering the various currying treatments applied to rough leather, such as fatliquoring, stuffing, dyeing and the various mechanical operations of setting, stretching, etc. It is intended

to show how widely the physical properties of leather may be varied and controlled by the proper application and selection of these numerous operations and treatments.

LE 404 **Properties of Leather** **(2-3)3**
[EN 351 and LE 401]

A practical and theoretical study of the characteristics of leather in relation to the end use. Studies are made on measuring and classifying the effect of changes in manufacturing procedure, both chemical and physical. Leather, because it is a natural product, varies considerably within the same hide. Thus, the nature of this variation is very important and the study of any changes affecting it is, in turn, important.

LE 405 **Leather Seminar** **(1-0)1**

A seminar on recent advances in leather research. Written and oral reports are required, and time is devoted to techniques of proper presentation of these reports.

LE 406 **Leather Seminar** **(1-0)1**

A continuation of LE 405.

LE 411-412 **Leather Problems** **(1-6)(1-6)6**
[LE 302]

This subject is designed primarily to enable the student to put into practical application the various scientific principles of physics, chemistry, mathematics, economics, etc. on problems of an industrial nature. This may encompass anything from the design and layout of any of a number of special leather plants to the suggested solution of practical problems which arise in the operation of a modern leather business.

LE 501-502 **Tanning Mechanism** **(3-0)3**

A study of the principle tanning processes in the light of modern concepts of chemistry. A critical appraisal of the information documented in the literature in comparison with actual experience taken from the technological aspects of tanning.

LE 503-504 **Microbiological Studies of Leather** **(3-5)5**

The general principles and laboratory techniques of microbiology are considered. Special emphasis is placed upon the bacterial and mycological problems arising in the leather industry.

LE 505-506 **Graduate Seminar** **(1-0)1**

Round-table discussion among staff members and graduate students on certain phases of thesis work, published scientific reports, and recent progress in leather technology.

LE 507-508 **Graduate Thesis** **Credits to be arranged**

MATHEMATICS

MA 107 Introduction to Mathematical Analysis (4-0)4

This subject is intended to provide a firm foundation for the student's subsequent studies in the nature and the use of mathematical functions. Topics considered include functions and graphs, logarithmic and exponential functions, the differentiation and integration of simple functions together with applications involving related rates, differentials, maxima and minima, areas, volumes, lengths of curves, pressure, and work.

MA 108 Calculus and Analytic Geometry (5-0)5

[MA 107]

The conic sections; equations of motion; mean value theorem; the differentiation and integration of trigonometric, inverse trigonometric, logarithmic, and exponential functions; centroid and center of mass; the theorems of Pappus; moment of inertia; polar coordinates; determinants; synthetic division; properties of roots of higher-degree functions; the translation and rotation of curves; hyperbolic and inverse hyperbolic functions; and further applications to chemistry and physics.

MA 205 Calculus and Analytic Geometry (4-0)4

[MA 108]

Integration by parts, integration by partial fractions, other integral forms, parametric equations, differentiation of vectors, tangential and normal vectors, elementary vector analysis, solid analytic geometry, partial differentiation, multiple integrals, infinite series, and complex functions.

MA 206 Differential Equations (3-0)3

[MA 205]

The solution of ordinary differential equations and of partial differential equations of the first order and first degree and of forms in certain other orders and other degrees that lend themselves readily to solution. Practical applications to chemistry and engineering.

MA 301-302 **Advanced Calculus** (3-0)(3-0)6

[MA 206]

A further study of differential equations. The Laplace transformation, numerical methods for solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations arising in mathematical physics, and problems suitable for the use of a complex variable. Extensive applications.

MA 306 **Theory of Equations** (3-0)3

[MA 108]

Mathematical induction, complex numbers, integral and rational roots, solution by radicals, impossibility of certain geometrical constructions, number of real roots, isolation of a root, determinants, and approximate methods of solution.

MA 403-404 **Mathematical Techniques in the Physical Sciences** (3-0)(3-0)6

[MA 302]

Not offered in 1958-59

A subject designed to provide a knowledge of the more important mathematical functions and their properties and to develop facility in applying mathematical methods and techniques to problems in theoretical and applied physical science.

MA 406 **Mathematical Statistics** (3-0)3

[EN 351, MA 205]

Not offered in 1958-59

Measurements of dispersion, theoretical frequency distributions, tests of goodness of fit and independence, partial and multiple correlations; permutations, combinations, and probability; game theory.

MA 511 **Functions of a Complex Variable** (3-0)3

MA 512 **Fourier Series and Boundary Values** (3-0)3

Not offered in 1958-59

MA 513 **Tensors and Matrices** (3-0)3

MA 514 **Operational Mathematics** **(3-0)3**

Not offered in 1958-59

MA 515 **Mathematics of Engineering Systems** **(3-0)3**

Not offered in 1958-59

The solution of linear differential equations by classical methods and by modern methods, and the solution of nonlinear differential equations by various methods.

MA 591 or 592 **Graduate Thesis** **Credits to be arranged**

The graduate thesis covers an independent investigation undertaken by the student of a problem which is of interest to a member of the faculty and has the prior approval of the Department Head. The thesis must show ability and originality and must be a clear and systematic written presentation of the results.

PAPER

PA 301 **Pulp Technology** **(3-0)3**

[CH 211]

Lectures and problems concerning the technology of pulp manufacture by the ground-wood, sulfite, alkaline and semi-chemical processes. Bleaching methods are studied.

PA 302 **Paper Technology** **(3-0)3**

[CH 211]

Lectures and problems concerning the technology of paper manufacture. Material covered includes stock preparation, filling and loading, sizing, coloring, special additives, paper machine operation, and finishing.

PA 303 **Pulp Laboratory** **(2-6)4**

[CH 211]

This as well as subsequent laboratory work is designed with a research-type approach to develop the student's ability to plan and analyze the experimental work and to reach logical conclusions from the results. Studies are made of the principle wood, rag and wastepaper pulps. The work includes wood and pulp microscopy, bleaching, and evaluations of pulps for their papermaking value by physical and chemical testing methods. Detailed written and oral reports are required.

PA 304 **Paper Laboratory** **(2-6)4**

[CH 211]

Studies of the fundamental processing techniques used in paper manufacture. The work includes investigations of stock preparation, filling and loading, coloring, use of additives, and sheet formation. Detailed written and oral reports are required.

PA 401-402 **Practice Work in Industry** **(1-8)(1-8)8**

[PA 302 and 304, or equivalent]

In order to give the student as thorough a knowledge of industrial problems and practices as possible, it is planned, in cooperation with several mills and converting plants, to set up practice stations. The student will spend one full day each week at one of these stations working on technical problems of interest to the mill management, but under the supervision of a member of the Institute staff. May be taken either or both semesters.

PA 403 **Converting Technology** (3-0)3
[PA 302 and 304]

Lectures and problems concerning the technology of paper and paperboard conversion by mechanical, coating, impregnating, laminating and printing processes.

PA 405 **Converting Laboratory** (2-6)4
[PA 403, usually taken concurrently]

Study of and practice in the use of the common techniques employed in the paper and paperboard industry. Emphasis is given to the colloidal and rheological properties of materials used. Detailed written and oral reports are required.

PA 408 or 409 **Mill Inspections** (1-4)2

Mill visits involving the observation of operations in various types of pulp, paper, paperboard, and converting mills. A formal, detailed written report of the observations made on each visit is required.

PA 413 or 414 **Paper Problems** (2-6)4

The senior is given an opportunity to work on a problem connected with some phase of the pulp, paperboard, or converting industry. Original application of accumulated knowledge of chemical and engineering principles is expected. Problems are selected by the student in collaboration with the staff and an advisory committee from the industry. One detailed formal report is required.

PA 501-502 **Graduate Thesis** (1-9)(1-9)8

Every graduate student is required to prove his ability to carry on independent research by presenting a thesis on an approved subject.

PA 503-504 **Plant Design** (4-0)(4-0)8
[CH 333, CH 442, PA 302]

Design of a paper, boardmaking, or converting process and plant. Included are the material and labor requirements, equipment selection (or design where commercial equipment is not available), the plant layout, and complete economic analysis. One detailed, formal written report including blueprints of equipment and plant layout is required. Principal reference texts: Vilbrandt, *Chemical Engineering Plant Design;* Tyler, *Chemical Engineering Economics.*

PA 505-506 **Advanced Papermaking and Paper Converting** (2-6)(2-6)8

Nonfibrous raw materials used in the specialty papermaking and paper-converting fields with emphasis on recent developments and new uses. These materials are studied with regard to their chemical and physical properties, the technology of application, and processed sheet properties.

PA 507-508 **Graduate Seminar** (1-0)(1-0)0

Every graduate student is required to attend a weekly seminar with the staff. Student thesis progress, articles in recent literature, and unpublished recent developments in the field are discussed.

PHYSICS

PH 103 **Physics** (4-1)4

[MA 107 taken concurrently]

The principles of mechanics, including composition and resolution of vectors, statics, moments, rectilinear motion, Newton's second law, motion of a projectile, work and energy, impulse and momentum, circular motion, rotational kinematics and dynamics, elasticity, harmonic motion, hydrostatics, hydrodynamics, and viscosity.

PH 104 **Physics** (4-1)4

[MA 108 taken concurrently, PH 103]

Heat, sound, and the basic principles of electricity and magnetism, including the following topics: thermometry, quantity of heat, change of state, heat transfer, thermal properties of matter, the first and second laws of thermodynamics, wave motion, vibrating systems, acoustical phenomena, Coulomb's law, potential, d.c. circuits, the magnetic field, galvanometers, ammeters, voltmeters, wattmeters, the d.c. motor, magnetic field of a current and of a moving charge, induced electromotive force, capacitance and inductance, and magnetic properties of matter.

PH 205 **Physics** (3-2)4

[MA 205 taken concurrently, PH 104]

Electricity and optics, including the following: transients in circuits containing inductance, capacitance, and resistance; thermoelectricity; ferromagnetism and ferroelectricity; alternating currents; electromagnetic waves; electronic phenomena; the nature and propagation of light; reflection and refraction at a single surface; lenses and lens aberrations; optical instruments; illumination; color; chromaticity diagrams; interference and diffraction; resolution; polarized light; and properties of crystals.

PH 206 **Physics** (3-2)4

[PH 205]

Modern physics, including the atomic nature of matter and electricity, variation of mass with velocity, isotopes, the nature of radiant energy, black bodies and the origin of the quantum theory, photoelectricity, spectra, Bohr's theory of the atom, X-ray spectra, waves associated with material particles, the spinning electron,

Pauli's principle, magnetic moment of an atom, the periodic system and quantum numbers, molecular structure, radioactivity, elementary particles, scattering and absorption of particles and photons, transmutation, fission, reactors, fusion, cosmic rays, mesons, hyperons, and relativity.

PH 211 **Intermediate Mechanics** **(3-0)3**
[MA 205 taken concurrently, PH 104]

Motion under an inverse square force, attractive or repulsive. Damped and forced vibrations. Elements of related mathematical topics, including vector analysis. Dynamics of a rigid body. Gyroscopic motion.

PH 222 **Intermediate Thermodynamics** **(3-0)3**
[MA 206 taken concurrently, PH 104]

Kinetic theory of gases. First and second laws of thermodynamics. Standard cycles. Equilibrium between phases. Chemical equilibrium. Thermoelectric phenomena. Nonquantum theory of black-body radiation. Third law of thermodynamics.

PH 244 **Optical Instruments** **(1-2)2**
[PH 206 taken concurrently]

The basic laws of optics and their application to various optical instruments used in industry, such as the microscope, telescope, refractometer, and colorimeter. Considerable emphasis in the laboratory work is placed on the general use of the microscope.

PH 251 **Intermediate Electricity** **(3-3)4**
[MA 205 and PH 205 taken concurrently]

Electric field, potential, Gauss' law, dipoles, Poisson's and Laplace's equations, image problems, dielectric theory, energy, capacitance, force, electric current, d.c. circuits, steady magnetic fields, electromagnetic induction, magnetic properties of matter, L-C-R circuits, analysis of a.c. circuits, and Maxwell's equations.

PH 254 **Electronics** **(3-3)4**
[PH 251]

The characteristics of vacuum and gaseous electron tubes and the properties of circuits which include them in such basic functions as rectifying, amplifying, oscillating, and modulating. Positive and negative feedback; circuit response to wave forms; differentiating, integrating, clipping, and other circuits; transistors and their circuits. Electronic instruments of importance to the physicist and mathematician.

PH 301 or 302 — Advanced General Physics — Credits to be arranged

[Permission of instructor]

Selected topics in mechanics, heat, sound, electricity, optics, and modern physics presented on an advanced level and emphasizing the interdependence of higher mathematics, classical physics, and practical concepts of engineering.

PH 312 — Physical Mechanics — (3-0)3

[PH 211]

Introduction to the calculus of variations, generalized coordinates, Hamilton's principle, theory of vibrating systems, normal coordinates, and elementary boundary value problems.

PH 321 or 322 — Electronics — Gen. Eng. (3-2)4

[PH 205] — Others (3-1)3

The principles of alternating currents as a background for the understanding of electronic circuits. The elements of vacuum and gaseous tube characteristics and of circuits containing such tubes for the purpose of rectification, amplification, and oscillation. Industrial photoelectric relays, time delay relays, and Thymotrol motor controls.

PH 323 — Statistical Mechanics — (3-0)3

[PH 222]

Introduction to the calculus of probabilities. Maxwell-Boltzmann statistics, Bose-Einstein statistics, Planck's theory of blackbody radiation, and Fermi-Dirac statistics.

PH 354 — Electromagnetic Theory — (3-0)3

[MA 302 taken concurrently, PH 251]

Theory of the electromagnetic field, polarization, solutions of Laplace's equation, magnetic potentials, Maxwell's equations, the wave equation and its application to cavities.

PH 355 — Physical Electronics — (3-3)4

[MA 206, PH 206]

Ballistics of charged particles in electric and magnetic fields, electron optics, electrons in metals, the kinetic theory of gases, conduction in a gas, the effects of ionized regions on radiation, elements of radioastronomy, counters and scaling circuits, photoelectric and photomultiplier tubes, and filters.

PH 358 **Electrical Measurements** (2-3)3
[MA 206, PH 206]

Precision of measurements, zero frequency and low frequency measurements by both deflection and null methods, amplifiers and tube electrometers, oscillographs, measurements at high frequencies, magnetic measurements, electrical measurements in mechanics, heat, acoustics, optics, and nuclear science.

PH 361 or 362 **Intermediate Nuclear Physics** (3-0)3
[MA 206, PH 206]

An experimental and theoretical treatment of alpha, beta, and gamma decay, particle detection, neutron diffraction, nuclear forces, and p-p and n-p scattering. The elements of wave mechanics.

PH 401 **Textile Microscopy** (2-3)3
[PH 205]

Applications of the microscope to textile materials. Methods of sectioning, measurement of cotton immaturity and mercerization, determination of denier of rayon, wool grading, fiber identification, quantitative analysis of fiber mixtures and their practical applications. Some of the more advanced aspects of critical microscopy which are essential for the best visual work and photographic practice are considered. Some time is devoted to photographic work and the use of polarized light.

PH 402 **Textile Physics** (2-2)3
[MA 205, PH 206]

Textile Physics is designed primarily for graduate students but may be taken by seniors who have sufficient knowledge of elementary college physics, microscopy and testing. It deals in an analytical and experimental manner with the principles of advanced physics which have important applications to textile technology. The topics taken up include heat transmission of textile materials; color measurements; calculation of tristimulus values; transformation to dominant wavelength, colorimetric purity, and brightness; measurement of refractive index of fibers; applications of phase microscopy; fluorescent microscopy; use of X-ray diffraction methods to determine crystal orientation and structure of fibers; spectrographic analysis; investigation of mineral elements in textile fibers; and accurate methods of measuring stress, strain, and viscosity.

PH 411-412 **Quantum Mechanics** (3-0)(3-0)6
[MA 403-404 taken concurrently, PH 431 or 432]

PH 421 **Physical Thermodynamics** **(3-0)3**

[MA 302, PH 222]

Not offered in 1958-59

PH 431 or 432 **Theory of Vibrations and Sound** **(3-0)3**

[MA 301, PH 312]

Free, damped, and forced oscillations; forcing by pulses; coupled oscillations; the flexible string; end conditions; perturbations; the vibration of bars, membranes and plates; sound waves; acoustic impedance; the radiation and scattering of sound; normal modes; and reverberation. Applications are stressed.

PH 443 **Spectroscopy** **(2-3)3**

Not offered in 1958-59

PH 461-462 **Nuclear Physics** **(3-0)(3-3)7**

[PH 362; MA 403 and PH 411-412 taken concurrently]

Not offered in 1958-59

PH 471-472 **Solid State Physics** **(3-0)(3-3)7**

[PH 411-412 taken concurrently]

Not offered in 1958-59

PH 501 or 502 **The Physics of Color Measurement** **Credits to be arranged**

[MA 206, PH 206]

The philosophy and practice of modern colorimetry. Colorimeters, their uses and limitations, spectrophotometers, tristimulus values, dominant wavelength and purity, the "standard observer" concept, the Munsell system, the Ostwald system, color tolerances, gloss and body color, illuminants, and industrial applications.

Laboratory instruments available consist of brightness testers, monochromatic and trichromatic colorimeters, recording and visual spectrophotometers.

PH 503 or 504 **Spectrographic Methods** **(2-3)3**

[PH 206]

The theory and application of the spectrograph for the qualitative and quantitative analysis of materials. The Bohr theory, quantum mechanics, atomic models, and the theoretical prediction of line and bend spectra. Special attention is placed in the laboratory on the analysis of elements in paper, leather, and textile samples, and individual problems are assigned to the students.

PH 505 or 506 — **X-Ray Diffraction** — **(2-3)3**
[PH 206]

The theory of X-ray diffraction and its application to the structure of matter.

PH 507 or 508 — **Electron Microscopy** — **(1-3)2**
[PH 206]

Basic methods in the practice of electron microscopy, including specimen preparation, use and operation of the electron microscope, vacuum techniques, and photography. This work is supplemented with special studies on selected topics.

PH 514 — **Advanced Statistical Mechanics** — **(3-0)3**
Not offered in 1958-59

PH 515 — **Advanced Quantum Mechanics** — **(3-0)3**
Not offered in 1958-59

PH 518 — **Relativistic Particle Mechanics** — **(3-0)3**
Not offered in 1958-59

PH 523 — **Low Temperature Physics** — **(3-3)4**
Not offered in 1958-59

PH 531 — **Acoustics** — **(3-3)4**
Not offered in 1958-59

PH 534 — **Crystal Vibrations** — **(3-3)4**
Not offered in 1958-59

PH 553 — **Piezoelectricity and Ferroelectricity** — **(3-3)4**
Not offered in 1958-59

PH 562 — **Advanced Nuclear Physics** — **(3-0)3**
Not offered in 1958-59

PH 563 — **Microwave Spectroscopy** — **(3-3)4**
Not offered in 1958-59

PH 565 — **Nuclear Resonance Methods** — **(3-3)4**
Not offered in 1958-59

PH 568 — **Neutron Diffraction Analysis** — **(3-0)3**
Not offered in 1958-59

PH 575-576	**Problems in Solid State Physics** Not offered in 1958-59	(3-0)(3-3)7
PH 581	**Information Theory** Not offered in 1958-59	(3-0)3
PH 583	**Relativity Theory**	(3-0)3
PH 586	**Field Theory** Not offered in 1958-59	(3-0)3
PH 588	**Computers** Not offered in 1958-59	(3-0)3
PH 591 or 592	**Graduate Thesis**	Credits to be arranged

The graduate thesis covers an independent investigation undertaken by the student of a problem which is of interest to a member of the faculty and has the prior approval of the Department Head. The thesis must show ability and originality and must be a clear and systematic written presentation of the results.

PLASTICS

PL 301-302 Introduction to Plastics Technology (3-3)(3-3)8

History, definitions, classes, properties, and applications of plastics. Raw materials and manufacturing processes. Methods of processing plastics materials including compounding, molding, casting, extruding, laminating, fabricating, and finishing. Evaluation and development of typical plastics problems. Laboratory instruction in the processing and fabrication of plastics materials.

PL 401-402 Advanced Plastics Technology (2-3)(2-3)6
[PL 301-302]

Applications of plastics as engineering materials. Product, equipment, and mold design. Correlation of composition, processing, and fabricating with product design and applications. Continuation of laboratory instruction in processing, molding, and fabrication.

PL 403-404 Properties of Polymers (2-3)(2-3)6
[Open to seniors only]

This subject includes the study of important engineering properties of plastics materials; theory of testing; the examination of testing techniques, equipment, and standard ASTM methods for evaluating mechanical, thermal, electrical, and optical properties.

PL 411-412 Plastics Seminar (1-0)(1-0)2
[Open to seniors only]

Informal discussions of topics in, or related to, plastics engineering based on literature study conducted by the individual.

TEXTILES

TE 201-202 — Fiber Technology — (4-0)(3-0)5

A study of the important textile fibers, both natural and man-made. Classifications, origins, marketing, and consumption. Stress is placed on their basic physical and chemical properties and their relationship to processing and utilization.

TE 203 — Textile Fibers — (4-0)3

Similar to TE 201-202, but less detailed. Not open to students in the Textile Technology course.

TE 204 — Yarn Technology — (7-2)5
[EN 205, TE 201]

This subject introduces the fundamental theory and practice of yarn manufacturing by the cotton, woolen, worsted, and filament systems. The aspects covered in TE 204 deal with the theory of yarn manufacture, the manufacture of yarns by the woolen yarn system, and the utilization of reclaimed fibers. The allocation of time is:

TE 204T	Theory	(2-0) 1
TE 204W	Woolen System	(3-2) 3
TE 204R	Reclaimed Fibers	(2-0) 1

TE 206 — Yarn Manufacture — (3-3)4
[TE 203]

Similar to TE 204, but less detailed. Laboratory work consists of demonstrations only. Not open to students in the Textile Technology course.

TE 207-208 — Color — (2-0)(2-0)4

A study of color, value and chroma using the Munsell Color System. Several plates painted by the student show the application of color to textiles. These plates include perfected harmony and distribution in patterns illustrating stripes, checks, plaids, and decorative designs. The influence of colors upon one another is stressed to equip the student with a working knowledge which will aid him in his choice of color for the fabric in question.

TE 211-212 — Color — (1-1)(1-1)2

Similar to TE 207-208, but less detailed.

TE 300 **Fabrics** **(2-0)2**

[Permission of instructor]

This subject is designed to acquaint the student with many of the important fabric types in use today for wearing apparel, home furnishings, and industrial uses. An analytical discussion approach is used so that the student may not only identify the fabrics but also understand the significance of the weave, design, yarns, etc., used.

TE 301-302 **Yarn Technology** **(7-6)(7-6)14**

[TE 204]

A continuation of TE 204. The allocation of time is:

TE 301C	Cotton System	(4-3) 4
TE 301W	Worsted System	(3-3) 3
TE 302C	Cotton System	(3-3) 3
TE 302W	Worsted System	(2-3) 3
TE 302F	Filament System	(2-0) 1

TE 303-304 **Fabric Technology** **(3-4)(3-4)8**

[TE 301-302, taken concurrently]

A study is undertaken of the fundamental theory and practice relating to the design, construction, and analysis of commercial fabrics, regardless of the fibers and/or yarns involved. During this period the basic designs and weaving aspects are covered. The allocation of time is:

TE 303W	Weaving	(1-2) 1½
TE 303D	Design	(2-2) 2½
TE 304W	Weaving	(1-2) 1½
TE 304D	Design	(2-2) 2½

TE 307-308 **Yarn Manufacture** **(3-3)(3-3)8**

[TE 206]

A continuation of TE 206. Not open to students in the Textile Technology course.

TE 309-310 **Fabric Manufacture** **(2-2)(3-3)6**

[TE 307-308, taken concurrently]

An abbreviated version of TE 303-304 and TE 401-402. Laboratory work consists of demonstrations only. Not open to students in the Textile Technology course.

TE 311 **Handloom Weaving** **(0-3)1**

The handloom is used as the means of producing in a minimum amount of time many different fabric constructions, utilizing yarn of different diameters, types and color.

TE 319 **History of Costume and Adaptions** **(1-2)2**

A general coverage of typical costume through the ages from the early Egyptian to the present. The student is expected to make many modern adaptions inspired by period costumes.

TE 323 **Surface Design Fundamentals** **(0-2)1**

Fundamentals of surface design are presented to develop an understanding of various surface patterns and rhythms for pleasing distribution of line and form.

TE 324 **Applied Decorative Design** **(0-2)1**
[TE 323]

Application of the fundamentals learned in TE 323 toward creation of surface patterns for prints and Jacquards.

TE 327-328 **Elements of Textile Manufacture** **(2-2)(2-2)6**

The elements of fiber preparation, yarn manufacture by all the common systems, weaving, and knitting are presented in a survey fashion. Laboratory consists of demonstrations only.

TE 352 **Fabric Draping** **(0-3)1**

The application of fabric to form for the purpose of understanding fully the use and limitations of various fabrics used in garments.

TE 401-402 **Fabric Technology** **(5-7)(5-7)12**
[TE 304]

A continuation of TE 303-304. The allocation of time is:

TE 401W	Weaving	(1-2) 1½
TE 401D	Design	(3-4) 3½
TE 401C	Color	(1-1) 1
TE 402W	Weaving	(1-2) 1½
TE 402D	Design	(2-3) 2½
TE 402K	Knitting	(2-2) 2

TE 403-404 **Textile Evaluation** **(2-2)(2-2)6**
[CH 102, EN 352, PH 206]

This subject is designed to provide a foundation for more advanced work in testing, and is of sufficient breadth to benefit those students whose main need is an understanding and appreciation of the scope of testing and evaluation in the textile industry. The subject matter covers an applied approach to the statistical treatment of experimental data, and the basic mechanical or physical, chemical, and optical tools and techniques available to the industry for

product control, development, and evaluation. Primary emphasis is placed upon an understanding of the principles involved and an integration of the various phases of textile testing into a unified whole.

TE 405-406 — **Finishing Technology** — **(4-2)(0-4)6**
[CH 302; TE 304 or 310]

Lectures and pilot plant laboratory work in all major physical and chemical operations necessary for the conversion into the finished state of all fabrics commonly used, regardless of fiber content. The allocation of time is:

TE 405C	Cotton System	(2-1) 2
TE 405W	Woolen and Worsted System	(2-1) 2
TE 406C	Cotton System	(0-2) 1
TE 406W	Woolen and Worsted System	(0-2) 1

TE 407 — **Knitting** — **(2-3)3**

Similar to TE 419, but with less laboratory work.

TE 411-412 — **Jacquard Design and Weaving** — **(1-2)(1-2)4**
[Permission of instructor]

Weaving on the Jacquard loom and the various tie-ups in common use. Instruction includes the sketching of original designs as applied to particular fabrics. The student is taught to transfer his original sketch to cross-section design paper, to choose the proper weave for both the background and foreground, to cut cards and lace, and to weave the fabric.

TE 413 or 414 — **Jacquard Design** — **(0-2)1**
[Permission of instructor]

The student is taught to transfer a given motif to cross-section paper, to choose the proper weave for the background and the foreground, and complete a Jacquard design. A sufficient number of cards are cut and laced to enable the student to appreciate the complete operation from the motif to the loom.

TE 415 — **Woolen and Worsted Mill Organization** — **(4-0)3**

A recapitulation of the routine covered in previous wool textile manufacturing subjects. Mill layouts are organized to make definite yardages of specific fabrics using modern machinery by both the woolen and worsted systems of manufacture.

TE 417 — **Cotton Mill Organization** — **(4-0)3**

This subject correlates all of the work on cotton manufacturing. Starting with a study of actual mill organizations the class is carried

forward to problems in developing new organizations for specific types of products. The adaptations for long draft and for the handling of staple fibers are carefully covered. Calculations are made for the machinery necessary to keep plants in balance with some consideration of the best arrangements for economical handling.

TE 419 Knitting (2-5)4

[Permission of instructor]

A broad survey of the important types of knitting. Considerable stress is placed on the various stitches and the characteristics of fabrics from each. Starting with flat machines, the work advances through small ribbers, automatic hosiery machines, full-fashioned hosiery machines, underwear machines and warp knitters. The production, design, and analysis of knit fabrics and the classifications and routines for manufacture of hosiery and underwear are included.

TE 422 Advanced Textile Design and Analysis (2-1)2

[Permission of instructor]

The first half of the semester is devoted to the study of Leavers lace including history, manufacture, finishing, a detailed study of the Leavers machine, and the basic principles of lace design and drafting. The second half of the semester covers a study of embroideries and rugs. Schiffli embroidery includes the Schiffli machine, basic principles of Schiffli design, manufacturing, finishing, and types and end uses of embroidery. Rugs include a study of the principles of construction and the analyses of chenille, Wilton, Brussels, tapestry, velvet and Axminster carpets.

TE 425 or 426 Advanced Knitting (2-5)4

[TE 419]

This is an advanced subject for students who are specializing in knitting. With the approval of the Department Head, the student may select a particular field from the various sections of the knitting industry and concentrate on its problems.

TE 429-430 Finishing—Cotton and Synthetics (2-1)(1-2)4

[CH 202, 356, 364; TE 328]

The physical and chemical phases of finishing fabrics made of cotton and man-made fibers. Primary emphasis is upon finishing theory. The laboratory phase of the subject is covered during the second semester, with emphasis upon the chemical nature of the processes.

TE 431 or 432 **Advanced Weaving** **(2-3)3**
[Permission of instructor]

Advanced work on the Crompton & Knowles looms, including the overhead multiplier, the filling mixer, and the tricolor automatic loom. Advanced work on the dobby looms, including leno and terry attachments. Other advanced areas such as Jacquard heads, harness mounting problems, and carpet weaving are also covered.

TE 434 **Cotton Waste Processing** **(1-2)2**
[TE 301 or 307]

A study of the methods and machinery used in processing cotton wastes and/or new cotton handled on waste machinery. The lectures consider the sources of the various wastes, by-products of the cotton industry, nonwoven fabrics, their preparatory treatment, and the manufacturing processes. Laboratory work includes the study of ordinary processing wastes, their treatment in preparation for processing, and experiments on machinery used for yarn manufacture by the waste system. Some time is also devoted to investigations of problems confronting the waste industry, and each student presents a paper in class on an assigned topic.

TE 435 **Woolen and Worsted Design** **(1-2)2**
Analysis and construction of woolen and worsted fabrics.

TE 437 **Weaving Laboratory** **(0-3)1**
Application of theories learned in textile manufacturing classes.

TE 439-440 **Finishing—Woolen and Worsted** **(2-1)(1-2)4**
[CH 202, 356, 364; TE 328]

The physical and chemical phases of finishing fabrics made of wool fibers and wool blends. Primary emphasis is upon finishing theory. The laboratory phase of the subject is covered during the second semester, with emphasis upon the chemical nature of the processes.

TE 444 **Jacquard Design** **(1-2)2**
Instruction includes work on original sketch, transfer to cross-section paper, and indication of weave for background and foreground, in order to cut cards and lace for the Jacquard loom.

TE 449-450 **Finishing Technology** **(2-2)(2-2)6**
[TE 328]

A general survey of the conversion of grey fabric of any content to a finished fabric. Clothroom, bleachery, dyehouse, and finishing equipment and practice. Both engineering and chemical phases are considered, but with emphasis on the former.

TE 466 **Advanced Cotton Fiber Technology** **(1-3)2**
[TE 201]

An advanced subject for students desiring detailed information on cotton fibers. Lectures deal with the effects of various chemical, mechanical, and growth modifications of cotton on the chemical, physical, and processing properties of the fiber. Problems are assigned for laboratory evaluation, and a paper discussing the evaluation is prepared by each student for class delivery.

TE 501 or 502 **Methods of Research** **(2-0)2**

A seminar to familiarize the student with the philosophy and methods of research, current problems in textile research and the further use of textile literature.

TE 503-504 **Structure and Properties of Fibers** **(3-0)(3-0)6**
[Permission of instructor]

The molecular structure and arrangement of molecules in fibers are considered with respect to giving a foundation to the understanding of the physical and mechanical properties and behavior of these textile raw materials. These properties are examined from a fundamental viewpoint so that a sound approach to the technological utilization of fibers in textiles can be established. Such aspects as polymer structure, order, intermolecular forces and flexibility, as they relate to stress-strain characteristics, viscoelastic behavior, etc., are discussed as well as the effects of environmental conditions on these factors. An introduction is made to the interrelation between fiber properties and yarn and fabric geometry in determining the behavior of textiles.

TE 511-512 Cotton Yarn Technology (4-2)(2-2)8
[Open only to graduate students with a mechanical engineering degree and with permission of the instructor]

An accelerated course covering the fundamental theory and practice of yarn manufacturing on the cotton system from bale through packaged ply yarn, including fancy yarns and sewing thread. Some of the more advanced research work on this material is also discussed.

TE 513 or 514 **Staple Fiber Processing—Cotton System** **(1-2)2**

[Permission of instructor]

This subject covers several phases of blending from fiber properties to yarn characteristics. Various methods and procedures for blending are discussed and illustrated. The processing of man-made fibers alone or in combination with natural fibers on regular and modified cotton-type machinery is studied with special attention to new developments. The laboratory work is arranged to illustrate or supplement the lecture material.

TE 516 **Quality Control—Cotton System** **(1-2)2**

[Permission of instructor]

While it is customary to point out defects in the materials during the processing in all lecture and laboratory work, this subject provides a logical summary of the usual defects which appear in different stages of cotton manufacture. The student is taught to recognize defective work and is given the usual causes of the common defects. Procedures and methods necessary to avoid or correct the defects are explained. Many samples of defects are used to illustrate this material. Effort is made to develop the diagnostic ability of the student so that he may readily recognize and remedy defects as he meets them.

TE 590-591 **Thesis Research** **Credits to be arranged**

Other subjects pertaining to textiles are listed under Chemistry, Engineering, and Physics. They are:

CH 302	Introduction to Textile Chemistry	(1-3) 2
CH 311	Advanced Quantitative Analysis for Textile Chemists	(2-4) 3
CH 355	Chemistry and Physics of Fibers	(2-3) 3
CH 356	Chemistry of Fiber Purification	(2-3) 3
CH 364	Textile Colloid Chemistry	(4-0) 4
CH 401	Introduction to Textile Chemistry	(1-3) 2
CH 408	Advanced Studies in Chemistry	Credits to be arranged
CH 422	Chemical Textile Testing	(2-3) 3
CH 453	Theory of Dyeing	(3-4) 4
CH 454	Industrial Dyeing and Printing	(2-8) 4
CH 461	Microbiology	(1-3) 2

CH 491	Textile Chemistry Literature Seminar	(2-0) 2
CH 501	Color Measurement	(1-3) 2
CH 505	Physical Chemistry of Dyeing	(2-3) 3
CH 512	The Physical Chemistry of Surface-active Agents	(1-3) 2
CH 551 or 552	Textile Testing Problems	(1-3) 2
CH 553-554	Evaluation of Finishing Agents	Credits to be arranged
CH 555-556	Textile Chemistry Seminar	(2-0) (2-0)4
CH 559	Instrumental Methods in Textile Research	(1-2) 2
CH 561-562	Polymer-Chemical Principles in the Technology of Organic Construction Materials	(3-0) (3-0) 6
CH 563-564	Special Topics in the Chemistry and Technology of Manufactured Fibers	(2-0) (2-0) 4
EN 304	Instrumentation for Textile Processing	(2-2) 3
EN 430	Engineering Design of Textile Structures	(3-0) 3
EN 431 or 432	Advanced Physical Textile Testing	(2-3) 3
PH 401	Textile Microscopy	(2-3) 3
PH 402	Textile Physics	(2-2) 3

THE GRADUATE SCHOOL

By act of the General Court of 1935, authority was given to the Lowell Technological Institute to confer degrees of Master of Science in the fields of Textile Chemistry, Textile Engineering, and Textile Technology to graduate students who satisfactorily complete an approved program. More recently, authority has been extended to include graduate programs leading to the Master of Science degree in Paper Engineering, Electronic Engineering, Leather Engineering, and Chemistry. The latest addition to the Graduate School is a program in Chemistry leading toward the Doctor of Philosophy degree. An option in this program allows for specialization in Textile Chemistry.

The graduate programs of study offered by the Institute provide for advanced specialized training required by technologists who contribute to industrial progress and human welfare through the application of scientific and engineering principles to existing industrial and human problems. The courses of study allow the graduate of the Institute, or of other colleges, who has specialized in either textiles, paper, leather, electronics, or chemistry to broaden his knowledge and skills in one of these areas and to develop a sound research approach to problems in the basic sciences, the engineering and development of new products, and industrial production. For those interested in teaching in these fields, the advanced classroom and seminar work, the research experience, and the opportunity to work with recognized leading teachers in the field are important.

ADMISSION TO THE GRADUATE SCHOOL

General Admission

To be eligible for admission to the Graduate School, an applicant must have received a bachelor's degree in an acceptable four-year course in which he has maintained a uniformly high scholastic rating. Both quality and quantity of the previous training will be considered. Selection of those applicants admitted will be based as far as possible on their ability to pursue graduate work of high quality.

Special Student Status

An applicant who meets the general admission requirements, but who wishes to concentrate on certain subjects in specialized techniques, or in some cases on special research programs, may request to be considered for Special Student Status. This work does not lead to a degree.

Acceptance as a special student is contingent upon the consent of the instructor in charge of each subject to which admission is desired.

Provisional Status

An applicant for admission who is unable to meet all the requirements for general admission may be accepted provisionally, if he satisfies the department in which he wishes to enroll that he is probably able to pursue graduate studies successfully.

The status of such a student will be changed to that of a graduate student upon demonstration of his ability to pursue graduate studies successfully as measured by the completion of his first semester's work with an average rating of at least 2.5 (80%).

Application Procedure

Those wishing to carry on graduate studies at this Institute should file application with the Director of the Graduate School. Applications may be obtained from the Office of the Graduate School.

Applications for admission should be complete and accurate and must be received not later than the first of June preceding the fall term in which the applicant wishes to enroll. Applications must be supported by letters from at least two persons qualified to judge the ability of the applicant to carry on graduate work and research. The letters should be sent directly from these persons to the Graduate School.

Transcripts of all undergraduate records (and graduate, if any) must be sent directly to the Office of the Graduate School by the institutions which the applicant has previously attended. All transcripts must be official, with appropriate seals and signatures. Records, descriptions of subjects, and letters must be in English. Each subject must be described in terms of content, scope, number of hours per week, and number of weeks duration. Lecture and laboratory time should be properly distinguished. If a catalogue giving such descriptions in English is available, the subjects taken may be clearly marked in a copy sent to the Graduate School.

A reading and speaking knowledge of English is necessary for an applicant to be considered for acceptance. Most of the

subjects are presented in lecture form, making it difficult for those who do not have a reasonably fluent command of the English language.

Except in unusual circumstances, applications will be acted upon and the applicant notified of the decision by July 1. Foreign applicants are urged to make application as early as possible so as to leave enough time for visa and other arrangements to be made.

GRADUATE COURSES OFFERED

Graduate programs leading to the Master of Science degree are offered in the fields of Chemistry, Electronic Engineering, Leather Engineering, Paper Engineering, Textile Chemistry, and Textile Engineering. A program leading to the Doctor of Philosophy degree in Chemistry with options in organic, physical or textile chemistry is also available to qualified applicants.

Because of the varied objectives of the graduate student, the course of study is arrived at through consultation with the student's graduate adviser.

Subjects numbered 500 and above are offered for graduate credit. A limited number of undergraduate subjects are available for graduate credit. The choice of these undergraduate subjects with graduate credit is subject to the approval of the Department Head.

Each program will include an original thesis.

EXPENSES

Tuition, fees, and other expenses for graduate students are for the most part the same as given on page 15 for undergraduates. In addition, however, every graduate student is required to bear the cost of binding two copies of his thesis for the Institute's files. The doctoral candidate must also pay to have his thesis microfilmed. Students will not be permitted to register for thesis work until these fees have been paid at the library.

MASTER OF SCIENCE DEGREE PROGRAMS

Chemistry

This program has been developed to provide opportunity for advanced study and research training in chemistry. Chemistry subjects include both general and specialized fields of study. Provision is also made for the student to elect certain advanced courses in related fields of mathematics, physics, and engineering.

Subject Requirements—Of the 20 credit minimum, exclusive of thesis, required in listed courses (see Requirements for Graduation at the end of this section), 15 credits must be taken in chemistry. Recommended courses include: CH 443-444 (may be taken either for graduate or undergraduate credit), CH 513-514, CH 521-522, CH 523-524, CH 531-532. Students may also elect CH 525-526, CH 527, CH 528, CH 529, CH 533, CH 534, CH 535-536, CH 538, and CH 561-562. All students must take Chemistry Seminar (CH 507-508). The remaining credits (five or more) may be taken in chemistry or in a related field such as physics, mathematics, or engineering. All subjects must be approved by the student's advisory committee.

Language Requirements—For the degree of Master of Science in Chemistry, the student must demonstrate his ability to read technical German.

Advisory Committee—The development of the student's program of study shall be the responsibility of an advisory committee consisting of three members from the faculty of the Division of Chemistry. This committee shall be appointed by the Director of the Graduate School upon the recommendation of the Division Chairman and shall include the thesis supervisor.

Thesis Examination—Each candidate for a Master of Science degree in Chemistry, upon completion of his thesis, shall present himself for an oral examination in the field of his thesis to an examination committee appointed by the Director of the Graduate School and consisting of his advisory committee and any additional faculty members considered desirable by the Director. While only members of the examination committee and the Director of the Graduate School may conduct the examination, all faculty members may attend. The examination shall be held after the thesis has

been accepted and within a period of two weeks prior to the close of the final semester. Application to take the examination must be filed by the student with the Director of the Graduate School at least one month prior to the close of the last semester. Each student has the right to one re-examination within a period of one year.

Electronic Engineering

The graduate program in Electronic Engineering is to be continued in 1958-59 on a limited basis. The program is restricted to

(a) graduates of the Lowell Technological Institute with a B.S. degree in Electronic Engineering, and

(b) qualified employees of neighboring industrial organizations which are participating in this graduate program.

Leather Engineering

A graduate program in Leather Engineering is offered for students who wish to work extensively in the field of leather technology. In general, only students possessing the B.S. degree in the chemical sciences or in leather engineering will be acceptable as candidates for the degree of Master of Science. In all cases, an examination of the undergraduate record of each candidate will be required before final acceptance. This is particularly necessary in cases where minor specializations in the field of chemistry or mathematics have not been satisfied. A program based on fulfilling these requirements would have to be completed along with the general requirements for the advanced degree. In the case of students who have not had any leather technology and/or histology and bacteriology, a certain portion of the graduate work would of necessity be required in these areas.

The following graduate subjects are offered in the department:

LE 501-502	Tanning Mechanism	(3-0) 3
LE 503-504	Microbiological Studies of Leather	(3-5) 5
LE 505-506	Graduate Seminar	(1-0) 1
LE 507-508	Graduate Thesis	Credits to be arranged

It is suggested that approximately 50% of the graduate programs should be chosen from the above subjects with the aid of the Department Head. The remainder should be chosen in fields

related to leather technology. Suggested subjects in this area would be

CH 503	Interpretation of Data	(2-0) 2
CH 512	Physical Chemistry of Surface-active Agents	(1-3) 2
GS 261-262	Technical German (but not for graduate credit)	

Paper Engineering

The graduate program in Paper Engineering is for the purpose of giving advanced work in papermaking, paper-converting or allied fields.

The Paper Engineering Department will consider graduate students from three different sources:

(a) graduates of the Lowell Technological Institute B.S. Paper Engineering course;

(b) paper engineering B.S. and M.S. graduates of other schools;

(c) general B.S. and M.S. engineering graduates with no previous paper training.

Students with the backgrounds given under (a) and (b) should be able to complete the work in one academic year. Students in group (c) should be able to complete the degree requirements in two academic years.

A graduate student in Paper Engineering will take approximately 50% of his graduate subjects (including thesis) in the Paper Engineering Department. The balance may be taken as electives related to the paper field and approved by the Department.

The graduate subjects offered in this Department are:

PA 501-502	Graduate Thesis	(1-9) (1-9) 8
PA 503-504	Plant Design	(4-0) (4-0) 8
PA 505-506	Advanced Papermaking and Paper Converting	(2-6) (2-6) 8
PA 507-508	Graduate Seminar	(1-0) (1-0) 0

Textile Chemistry

Graduate work in Textile Chemistry allows qualified students the opportunity to pursue advanced study in the physical chemistry of textile processing such as dyeing, wet finishing and fiber modification. Studies on the organic chemistry of dyes may also be undertaken. Recent studies have been on the theories of dyeing of natural

and synthetic fibers and the application of synthetic finishes. Such studies are carried out by graduate class work, seminars, and original thesis.

The following subjects must be included in the student's program:

First Semester:

CH 503	Interpretation of Data	(2-0) 2
CH 505	Physical Chemistry of Dyeing	(2-3) 3
CH 531	Chemical Thermodynamics and Kinetics	(3-0) 3
CH 555	Textile Chemistry Seminar	(2-0) 2

Second Semester:

CH 512 or	Physical Chemistry of Surface-active Agents	(1-3)2
CH 538	Rheology	(2-3)3
CH 556	Textile Chemistry Seminar	(2-0) 2

Recommended electives include CH 561-562 and CH 563-564.

Textile Engineering

Graduate work in Textile Engineering is offered so that qualified students may pursue advanced studies in the field of textiles. There is also the opportunity to conduct research on textile materials and processes. There is a broad enough selection of subjects and research topics so that those interested in the physical and mechanical properties of fibers and textile structures and methods of evaluating them, as well as those who wish to work at an advanced level on textile design, processing, or textile manufacturing equipment, will have the opportunity to do so.

The program for each student is arrived at after consultation with the Chairman of the Division of Textiles. The desires and needs of the student will be considered. Available subjects are listed under Textiles, Engineering, Mathematics, Chemistry, and Physics.

MASTER OF SCIENCE DEGREE REQUIREMENTS

Term of Residence

Applicants with a sufficient background in their chosen field of concentration will normally require one academic year of residence to complete the requirements for the master's degree. Those with no background will require a minimum of two years of residence.

Graduates of other colleges usually need more than one academic year to fulfill the degree requirements, even though they majored as undergraduates in their graduate field of specialization.

Candidacy for a Master's Degree

Admission to a master's degree program does not indicate that the student is a candidate for the master's degree. A student enrolled in a graduate degree program, who has established an acceptable scholarship record and has completed half of the required program, may make application to the Director of the Graduate School to become a candidate for the degree.

Application for approval of candidacy for the advanced degree must be filed after completion of one-half of the required program and not later than twelve weeks prior to the date on which the degree is to be conferred.

Requirements for Graduation

To be recommended for the Master of Science degree a candidate must have

(a) completed a course of study approved by the department in which he has been enrolled. The approved course of study is to have a minimum of 30 credit hours, including thesis. A minimum of 20 credit hours is to be spent in listed subjects, and the program should have no fewer than 5 credit hours of thesis work.

(b) completed a thesis (original research or other investigation, optional with department) approved by the department in which he has been enrolled, and successfully passed any oral or written examinations on his thesis required by the department at the time his thesis is submitted for final approval.

(c) maintained residence for at least one academic year.

(d) maintained an average rating of B in graduate subjects and passed all undergraduate subjects submitted for graduate credit with a grade of B or better.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

Chemistry

The doctoral program in Chemistry is designed to provide both advanced knowledge and research training in chemistry, particularly in the fields of organic, physical, and textile chemistry.

Plan of Program

The doctoral degree will normally require from three to four years of study beyond the bachelor's degree, and a minimum of two to three years beyond the master's degree.

The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his advisory committee or, pending its appointment, with his temporary adviser.

Immediately upon entrance, each student is given a set of three evaluation examinations administered by the Chemistry Division in the fields of organic chemistry, physical chemistry, and combined analytical-inorganic chemistry. The results of these examinations will serve as a guide for the student and advisory committee in planning the program of study.

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. His first year is usually devoted to graduate courses in the major branches of chemistry in preparation for his qualifying (candidacy) examinations. These examinations are taken preferably at or near the end of his third semester. The second year is devoted primarily to advanced courses in a special field of concentration in preparation for the major examinations which are normally taken at the close of his fourth semester of graduate study.

The second and final part of the program is devoted primarily to research leading to the doctoral thesis. However, students are encouraged to begin research as early as possible in their program of study.

Upon entrance to the doctoral program, each student is assigned an advisory committee. This committee is appointed by the Director of the Graduate School, based upon recommendation by the Chairman of the Chemistry Division, and consists of at least three members of the faculty, at least two of whom are from the faculty of the Chemistry Division. One member of the committee,

representing the student's major field of interest, serves as temporary chairman. After the student has selected his thesis supervisor, the temporary chairman of the advisory committee is replaced by the thesis supervisor who then serves as permanent chairman.

Course Offerings and Distribution

As a basis for the candidacy examinations, the following core of courses is recommended for first-year students in the doctoral program:

CH 531-532	Chemical Thermodynamics and Kinetics	(3-0)(3-0)6
CH 521-522	Physical Organic Chemistry	(3-0)(3-0)6
CH 443-444*	Advanced Inorganic Chemistry	(3-0)(3-0)6
CH 513-514	Physicochemical Methods	(2-4)(2-4)6

Additional courses may be taken in the minor or in the major field of concentration provided that prerequisites are met.

In the second year, courses supporting concentration in specific fields are available as follows, but selection is not restricted to those subjects listed below in a given field of concentration:

Organic Chemistry

CH 523-524	Organic Chemistry of Polymeric Species	(3-0)(3-0)6
CH 527	Metal-Organic Compounds	(3-0)3
CH 528	Steriochemistry	(3-0)3
CH 529	Heterocyclic Chemistry	(3-0)3

Physical Chemistry

CH 533	Statistical Mechanics for Chemists	(3-0)3
CH 534	Quantum Mechanics for Chemists	(3-0)3
CH 535-536	Advanced Topics in Physical Chemistry	(3-0)(3-0)6

Textile Chemistry

CH 501	Color Measurement	(1-3)2
CH 505	Physical Chemistry of Dyeing	(2-3)3
CH 512	Physical Chemistry of Surface-active Agents	(1-3)2
CH 553-554	Evaluation of Finishing Agents	Credits to be arranged
CH 538	Rheology	(2-3)3
CH 551 or 552	Textile Testing Problems	(1-3)2
CH 561-562	Polymer Chemical Principles in the Technology of Organic Construction Materials	(3-0)(3-0)6
CH 563-564	Special Topics in the Chemistry and Technology of Manufactured Fibers	(2-0)(2-0)4

*May be taken either for graduate or undergraduate credit.

Seminar

During each year of residence the student will be required to attend and to participate in graduate seminars. Normally, Chemistry Seminar, CH 507-508, (1-0) (1-0) 2, will be taken, but students wishing to specialize in Textile Chemistry may instead elect Textile Chemistry Seminar, CH 555-556, (2-0) (2-0) 4, during the first year of study.

Majors and Minors

The prospective candidate is expected to supplement his training in the major field of interest by electing a minor. To avoid overspecialization, this minor must be in a field outside of chemistry. The minor may be divided between two fields if the student so desires. Concentration in the minor field or fields should represent a minimum of 9 credits. Subjects in the minor are normally taken during the first two years of study.

DOCTOR OF PHILOSOPHY DEGREE REQUIREMENTS

Term of Residence

Work done only during the regular academic year from September to June can be counted toward residence credit. A minimum of one full academic year of study in residence is required of all candidates. A full year constitutes not less than 36 credit hours of work. Students carrying less than a full-time program must spend a proportionately longer time. Semesters in residence should be consecutive if possible.

All requirements for the doctorate must be completed within seven years after the student's entrance, and within four years after admission to candidacy. Extension of time beyond this limit may be granted only with the joint approval of the student's advisory committee and the Graduate School committee.

Candidacy for the Doctorate

To be admitted to candidacy for the doctorate, a student must have

(a) completed the first year's core of advanced courses in physical chemistry, organic chemistry, inorganic chemistry, and physicochemical methods and have had a satisfactory record in undergraduate training, graduate seminar, and collateral reading.

(b) filed a written request to take the qualifying examinations.

(c) passed these qualifying examinations which test his general knowledge. One day is devoted to an examination in each of the following areas: organic chemistry, physical chemistry, and combined inorganic-analytical chemistry.

(d) fulfilled the language requirements, as noted below.

(e) secured the approval of his advisory committee and the Division Chairman.

When the above requirements have been fulfilled, the Division Chairman will so notify the Director of the Graduate School in writing and recommend that the student be placed on the list of candidates for the Ph. D. degree. Admission to candidacy does not in any way guarantee the granting of the degree.

Requirements for Graduation

To be recommended for the Doctor of Philosophy degree, a candidate must have

(a) satisfied the residence requirements.

(b) pursued an approved program of study that includes the satisfactory completion of at least 90 credit hours beyond the bachelor's degree or equivalent. At least half of these credits will be in formal course work exclusive of seminars or thesis Graduate credit will be allowed only for grades of C or better in graduate (500) subjects (or certain advanced undergraduate subjects) and B or better in approved undergraduate subjects.

(c) demonstrated satisfactory reading ability in German and one other language (preferably French or Russian). Foreign students may under certain circumstances substitute their native tongue for one of the languages. Both language examinations must be passed prior to advancement to candidacy, and before extensive work on the thesis is begun.

(d) passed the qualifying examinations for candidacy.

(e) passed the major examinations in the field of concentration. These examinations are devoted primarily to the testing of the student's knowledge in his special field of concentration and will draw heavily on knowledge gained during his second full year of study in this particular area. They are given only when substantially all of the formal course work has been completed, normally at the end of the second full year (fourth semester). The

major examination is in two parts. The first part will be written and will extend over a period of one day. It will test the student's broad knowledge in his specific field of concentration. The second part of the major examination will be oral and will test the student's aptitude for research and his ability to organize and to develop a research problem. The examination will take the form of the defense of a proposition. The student will select a problem with the approval of his advisory committee.

(f) completed a satisfactory thesis. The doctoral thesis is designed to permit the student to demonstrate his ability to conduct original and independent research work. The results of the thesis investigation should contitute a definite contribution to knowledge in the field of specialization and should be suitable for publication. The field of the thesis investigation should be selected as soon as possible after admission to the graduate program, and the subject of the thesis must be approved by the advisory committee. As soon as the subject has been selected, the student must make his choice known to the Department Head who in turn will notify the Graduate School so that the list of theses in progress may be kept current. The thesis subject must be filed not later than two weeks after the student has been admitted to candidacy. While the nature of the results of the thesis investigation provides the basic criterion for determining the time required for the thesis, thesis credit will normally constitute about half of the total credit requirement. As a rule, from three to four semesters of full-time work will be required.

(g) passed a thesis examination. This is an oral defense of the student's thesis before the faculty of the Department of Chemistry and Textile Chemistry.

(h) satisfied all requirements as to tuition and fees.

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GRADUATE THESES
1946 — 1958

This bibliography lists titles of theses done during the 12-year period 1946 to 1958 by graduate students at Lowell Technological Institute, Lowell, Massachusetts. No thesis is for sale, loan, or distribution, but photocopies may be obtained for a nominal fee by writing to the Alumni Memorial Library at the Institute.

CHEMISTRY

1946 Landry, Rita P. A Systematic Scheme of Identification for Finishing Materials of Any Fabric.

1947 Boule, George R. Time-Temperature Effects on Cotton Fabrics.

Lyra, Mario S. Development of an Apparatus and Method for Determining the Water Permeability of Fabrics.

Manudhane, R. G., and C. C. Shah. Optimum Conditions for the Hypochlorite Bleach.

Prado de Mendonca, A. O. Study of the Formaldehyde-Ethyl Acetate Condensation to Produce Ethyl Acrylate.

Rao, D. Ranmanth. Reaction Study of Vinyl Acetate and Chloro-Acetic Acid.

Rocha, Ademar V., and Jose F. Valente. Investigation of the Reaction between B′, B′, Dichlorodiethyl Ether and Benzene in the Presence of Aluminum Chloride.

Singh, Kirpal. The Application of Anthraquinone Vat Dyes on Wool.

1948 Godiwala, Ramswarup G. Minimum Amount of Chrome Required for After-Chrome Dyeing.

Landry, Rita P. The Measurement of Dimensional Changes in Rayon Fabrics.

Willett, R. E. The Wet-Dry Strength Ratio as a Measure of the Degradation of Cotton.

Woo, Henry Kyi-oen. A Study of the Application of Direct Cotton Dyes on Nylon.

Yang, Y. L. The Effect of Certain Variables on the Rate of Shrinkage of Textile Fabrics.

1949 Chang, Leo S-Y. Union Dyeing of Wool-Viscose Fabric.

Hochschild, R. George. The Swelling Effects of Ammonium Thiocyanate on Textile Fibers.

James, E. P., and J. B. Masaschi. Time-Temperature Effects on Woolen and Viscose Fabrics.

✓ Na, Chung S. A Study of the Time-Temperature Effect on Nylon Fabric.

Solanki, U. V. Application of Synthetic Resins to Textiles on a Laboratory Scale.

1950 Charatz, Milton. Application of Positively Charged Rubber to Cotton Fabric.

Finnie, Jerrold N. The Swelling Effects of Sodium Thiocyanate on Textile Fibers.

Kopycinski, Joseph V. A System of Semi-Micro Qualitative Analysis for the Rare Elements.

Laksminarayanaiah, N. The Application of Cellulose Ethers to Textiles on a Laboratory Scale.

Petersen, R. Chemical Analysis of Wool Scouring Liquors.

Sheehan, Charles. A Study of the Accumulation of Nitrogen in Wool Scouring Liquors.

Trommer, Charles R. Measurement of Rate of Penetration of Surface-active Agents through Textile Materials.

✓ Wang, H. S. Time-Temperature Effects on Acetate Fabrics.

1951 Cherowbrier, E. Side-to-Center Shading of Carbonized Goods.

Denio, Ruth E., and Samuel A. Wood. The Curing of Urea Formaldehyde Resins by Convectional and Infrared Methods.

Feyler, Irving W., Jr. A Study of Complex Polysulfides Using Radioactive Tracers.

Gaidis, Leo P. Mechanism of Dyeing. Part I. The Effect of Sodium Sulphate, and Other Salts, on the Acid Dyeing of Wool.

Green, Arthur N. Deemulsification of Wool Scouring Waste Liquors Containing Synthetic Detergents with Special Reference to the Alkyl Aryl Sulfonates as the Detergent and Aluminum Salts as the Deemulsifier.

Lent, Joan Gregg. The Coefficient of Friction of Paper.

Matlin, Nathaniel A. Some Mechanical Properties of Paper.

Skalkeas, Basil G. The Influence of Yarn Modifications on Stress-Strain Properties.

Sumers, Robert W. Butanol Deemulsification of Non-ionic Synthetic Detergent Wool Scouring Effluents.

1952 Barry, Gerald F. A Study of a Method for the Measurement of Dye Penetration. Part II.

CATE, ALFRED L. A Study of a Method for the Measurement of Dye Penetration.

FEYLER, DONALD P. Studies in the Ultraviolet Absorption Spectra of N-(2-Nitroisobutyl) Arylamines.

GREENBERG, GERALD M. A New Method for the Removal of Soluble Impurities from Acid Dyes.

SHIPPEE, FRED B. Effect of Mechanical Agitation on the Acid Dyeing of Wool.

1953 BOCHES, MILTON. An Investigation of the Effect of Moisture, Load, and Speed on the Friction between Nylon Parachute Materials at Relatively High Speeds.

FINNIE, TREVOR A. Time-Temperature Effects on Materials Made from Dacron-Polyester Fiber.

LISTON, FLORENCE P. The Synthesis of a New Azo Dyestuff, Para-N-(2-Nitroisobutyl) Aminoazobenzene, and the Study of Its Absorption Spectra in the Visible Region at Varying Acidities.

LIU, ANDREW T-CHIU. The Interchangeability of Temperature and Agitation in the Rate of Dyeing.

OLNEY, ROBERT A. A Preliminary Investigation of the Factors Involved in the Study of Surface Fusion and High Temperature Effects on Nylon Parachute Ribbon.

PEIRENT, ROBERT J. An Investigation of Colorfastness Properties of Synthetic Fibers.

SAFIOEN, R. A Qualitative Study of Mechanical Agitation in the Acid Dyeing of Wool.

SETTY, S. R. A. K. Effect of the Form of the Substratum on the Rate of Dyeing.

1954 BARISH, LEO. Various Factors Which Influence the Shrinkage of Fabrics and the Development of an Accelerated Shrinkage Test.

BROWN, HERMAN. An Evaluation of Antistatic Agents on Nylon Parachute Cloth.

DEMAS, HARRY J. Friction and Lubrication of Nylon Parachute Materials.

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PACKING COEFFICIENT AND THE THERMAL CONDUCTIVITY OF TEXTILES*

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ABSTRACT

The relationship between packing coefficient and thermal conductivity is discussed for both cellular material and fibrous aggregates. Both of these simple forms are shown to have an initial decrease in thermal conductivity followed by an increase as the packing coefficient is varied from 0 to 1. An expression is developed for the minimum possible thermal conductivity attainable with fibrous aggregates for any value of packing coefficient. General relations for the simple forms are extended to textile fabrics. The thermal conductivities of several knitted and woven wool fabrics are compared with respect to their relative abilities to attain the minimum possible thermal conductivity at a particular value of packing coefficient for each fabric.

INTRODUCTION

The ability of a textile fabric to maintain body warmth in cold weather or to dissipate heat effectively in warm weather is one of its important functions. An engineering parameter of great importance in this respect is thermal conductivity. Textile fabrics are not homogeneous, solid bodies; hence, the term thermal conductivity is not altogether properly applied. However, since it is in common use, it will be used here, understanding that it means an over-all apparent thermal conductivity (1).**

The manner in which the thermal conductivity of fabrics varies and the factors which affect this variation are of importance not only in predicting the thermal characteristics of fabrics already in use but also in the design of new fabrics. More efficient utilization of fibers may be made if the fiber properties can be related to the final fabric thermal properties.

Packing coefficient is of interest as a subject for study with respect to its effect on thermal conductivity. It is one of the fabric properties easily determined and is important in evaluating the heat transmission characteristics of fabrics. The packing coefficient is defined here as the fraction of a unit volume of the fabric which is occupied by the fibers; it will be designated hereafter as ϕ_2. How this fabric property affects the thermal conductivity is best studied by first considering simpler systems and then applying the general relations observed in these systems to fabrics. The two simple systems which will be considered first are cellular materials and fibrous aggregates.

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*Based on material contained in a thesis by C. T. Derecho, Jr., submitted to Lowell Technological Institute in partial fulfillment of the requirements for the degree of Master of Science in Textile Engineering.

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**Numbers in parentheses refer to the Bibliography at the end of the paper.

VARIATION OF THERMAL CONDUCTIVITY WITH THE VALUE FOR PACKING COEFFICIENT IN CELLULAR MATERIAL

The flow of heat across a cellular material involves the operation of several transport mechanisms. There is the flow of heat through the walls of the cell by conduction, while across the cell radiation and convection occur. The walls of the cell may be partially transparent to infrared, in which case some radiation will travel through the solid material of the cell walls. In many cases the walls of the cell are thin in comparison with the cell size; therefore those factors which affect heat flow across the cell may be of more importance than those affecting heat flow through the walls in any consideration of the over-all heat flow through such material.

Cellular material may have its cells interconnected, or the cells may be separate from each other. This is of importance in considering the effect of cell size on the thermal conductivity, since a cell which may be too small to allow effective convection currents to be set up may be interconnected with other cells in such a way as to allow over-all circulation through the interconnected cells.

Mark and Stephenson (1) consider an idealized model of cellular material with cells taken as cubes arranged symmetrically side by side. The case they consider where the cell wall thickness is kept constant and the apparent density is increased is of particular interest, since it most closely approaches the conditions which prevail in fabrics. (In textile fabrics the fiber diameter might be taken to correspond to the cell wall thickness.) The existence of an optimum value (i.e., minimum thermal conductivity) is indicated as the apparent density of the cellular material is increased (Fig. 1). It is seen from the definitions of apparent density and packing coefficient that ϕ_2 is proportional to apparent density and that the constant of proportionality is the inverse of the density of the material composing the cell walls, or in the case of fibers, the density of the fibers. Therefore, the existence of an optimum value of density for minimum thermal conductivity will also mean the existence of an optimum value for the packing coefficient, whose value would be equal to the optimum density divided by the density of the wall material.

VARIATION OF THERMAL CONDUCTIVITY WITH THE VALUE FOR PACKING COEFFICIENT IN FIBROUS AGGREGATES

In fibrous aggregates a mass of fibers is arranged more or less at random, forming a network of air spaces of different shapes and sizes. The behavior of the thermal conductivity with variations in the value for the packing coefficient in such material may differ from that of cellular material but qualitatively might be expected to be related to it, depending upon how closely the fibrous aggregates approach the idealized model previously mentioned (1). Those factors which cause an increase in the thermal conductivity of cellular material should also cause an increase in the thermal conductivity of fibrous aggregates. Thus any increase in the "directness" (1) of the thermal path will cause an increase in convection and radiation; an increase in the apparent density, or packing coefficient, of the fibrous aggregate should increase the conduction effect.

The part that conduction plays in the over-all transfer of heat through fibrous aggregates is shown by Schuhmeister's relation (2). He considered a fibrous mass whose apparent density was constant over the whole thickness of the sheet. By assuming that heat transfer was by conduction only

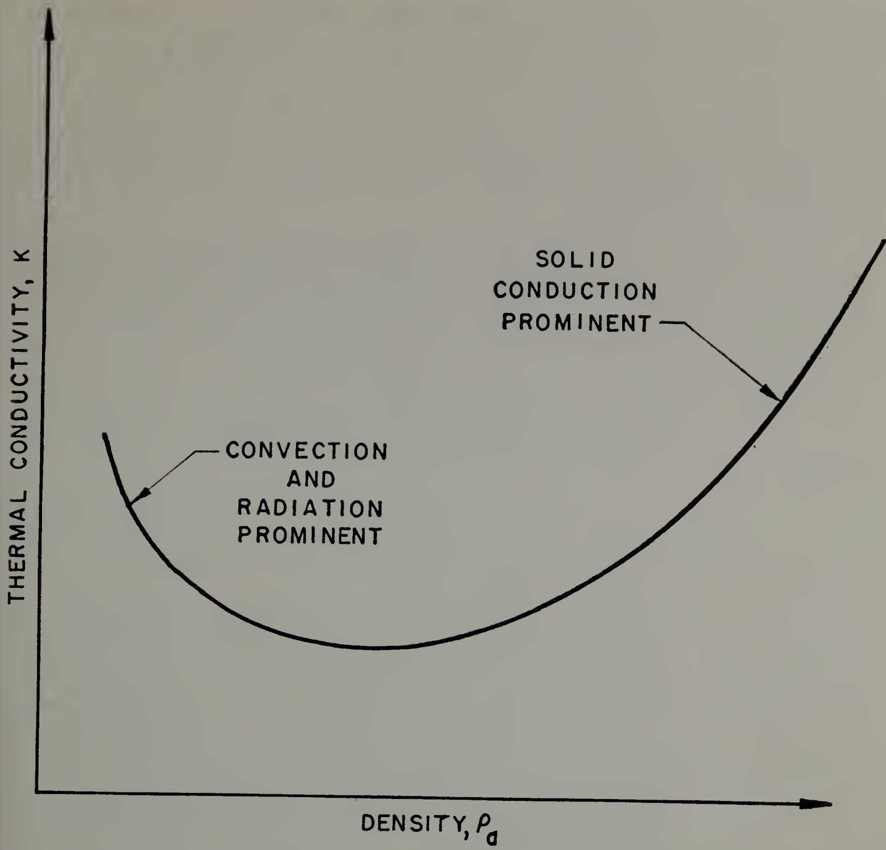

FIGURE 1.—Estimated variation of thermal conductivity as a function of density for fibrous material. Redrawn from reference (1).

through the fibers and the air in the pores, Schuhmeister derived the following relation:

$$k_m = x(k_1\phi_1 + k_2\phi_2) + y(\frac{k_1k_2}{k_1\phi_2 + k_2\phi_1}) \qquad [1]$$

where k_m = composite conductivity of the aggregate,

k_1, k_2 = coefficient of thermal conductivity of the air and the fiber respectively,

ϕ_1, ϕ_2 = volume fractions of the air and the fiber components respectively,

x, y = fiber orientation factors.

The values of x and y are such that

$$x + y = 1 \qquad [2]$$

Schuhmeister's assumption of random orientation leads him to state that the values of x and y should be ⅓ and ⅔ respectively. Because of

some preferential orientation of the fibers, the values of x and y can change, and Baxter indicates that the values $x = 0.29$ and $y = 0.71$ give a better fit for his data (3). Finck (4) shows that the effect of fiber orientation relative to the direction of heat flow is appreciable. He found that lower thermal conductivity values are obtained when the fibers are arranged perpendicular to the direction of heat flow, intermediate values for random orientation, and high values for fibers arranged parallel to the direction of heat flow.

Work by Baxter (3) and Speakman and Chamberlain (5) indicates that the relation derived by Schuhmeister holds true over the greater portion of the curve of apparent density vs. thermal conductivity. Figure 2 shows this clearly, especially at the higher values of apparent density (or packing coefficient). This supports the predicted behavior that solid conduction would be prominent at higher apparent densities.

The result of ignoring convection and radiation effects can be seen in Fig. 2. At low values of apparent density (or the region of low values for packing coefficient), the experimental points do not coincide with the predicted behavior from Schuhmeister's relation. It is seen that an increase in thermal conductivity occurs at very low apparent densities. Finck (4) shows that this point of minimum thermal conductivity occurs for most, if not all, fibrous aggregates. The curves which he found for jute, kapok, and bagasse are shown in Fig. 3.

That Schuhmeister's relation does not give a minimum thermal conductivity point can be shown if his relation is differentiated with respect to the packing coefficient. The result, equated to 0 and solved for ϕ_2, gives complex values only, no real root existing. This is expected, since the equation was derived on the assumption that heat transfer through the fibrous aggregate is solely by conduction.

Consider now the case of an air space between two parallel surfaces across which a temperature gradient is maintained. The heat flow from one surface to the other will be made up of radiation and convection, the latter in the limiting case being gaseous conduction. If fibers are now introduced into the air space, the amount of heat transferred will be affected and the value for the packing coefficient will increase.

The effect of the introduction of fibers on the convection component will be to reduce it. This reduction is due to decreases in directness and circulation (1). The degree will depend on the arrangement of the fibers, the number and size of the fibers, and the original size of the air space. Since fabrics usually have a thickness of less than one-half centimeter, one-half centimeter will be taken to be the distance between the surfaces for this present discussion. Air spaces of this order of magnitude do not support appreciable free convection currents under the temperature gradients normally encountered in fabric use. Thus free convection, not a large factor to begin with, is rapidly reduced even further with the insertion of fibers in the air space.

The radiation component of heat transfer will be affected in a manner similar to the convection component. Most textile fibers are partially transparent to infrared but would still absorb the greater portion of the incident radiation. The interposition of fibers cuts down direct radiation from the hotter surface to the cooler surface, since the intermediate fibers will have to reradiate the heat to the opposite side. It can be seen that the radiation component is reduced though not as rapidly as the convection component.

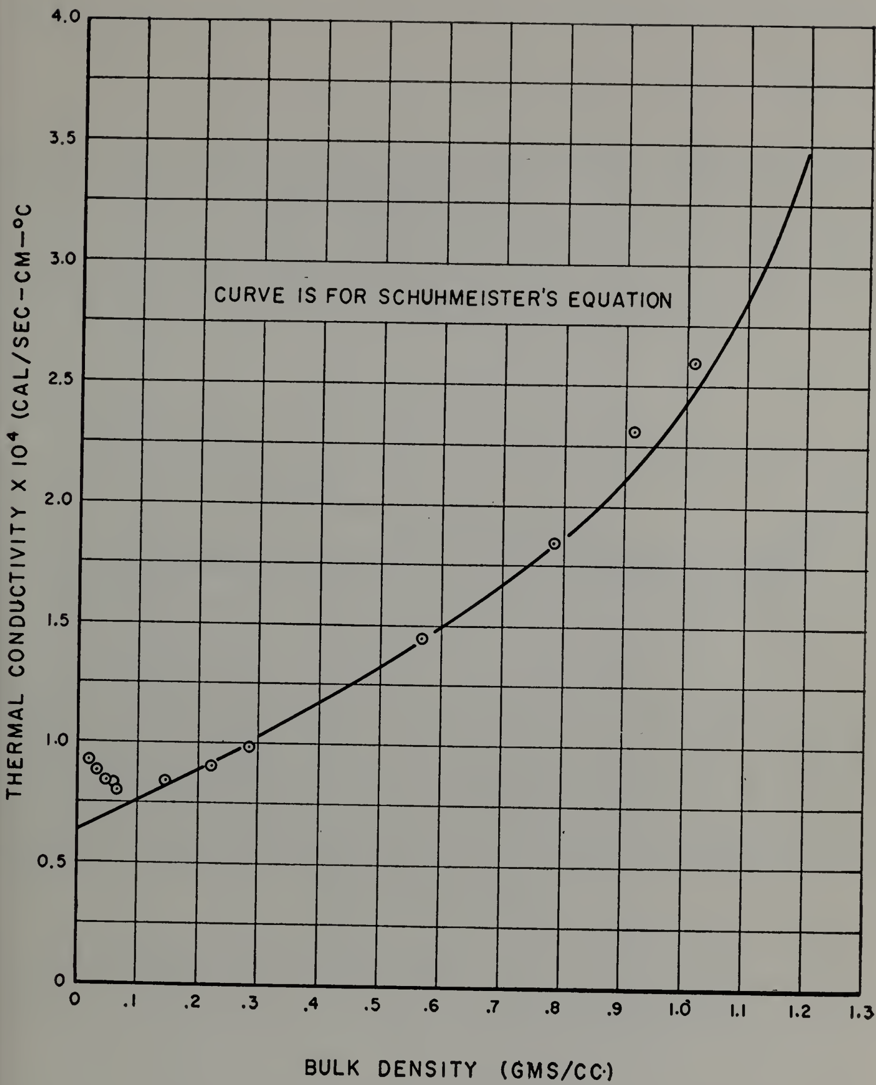

FIGURE 2.—Thermal conductivity as a function of bulk density for wool. Redrawn from reference (3).

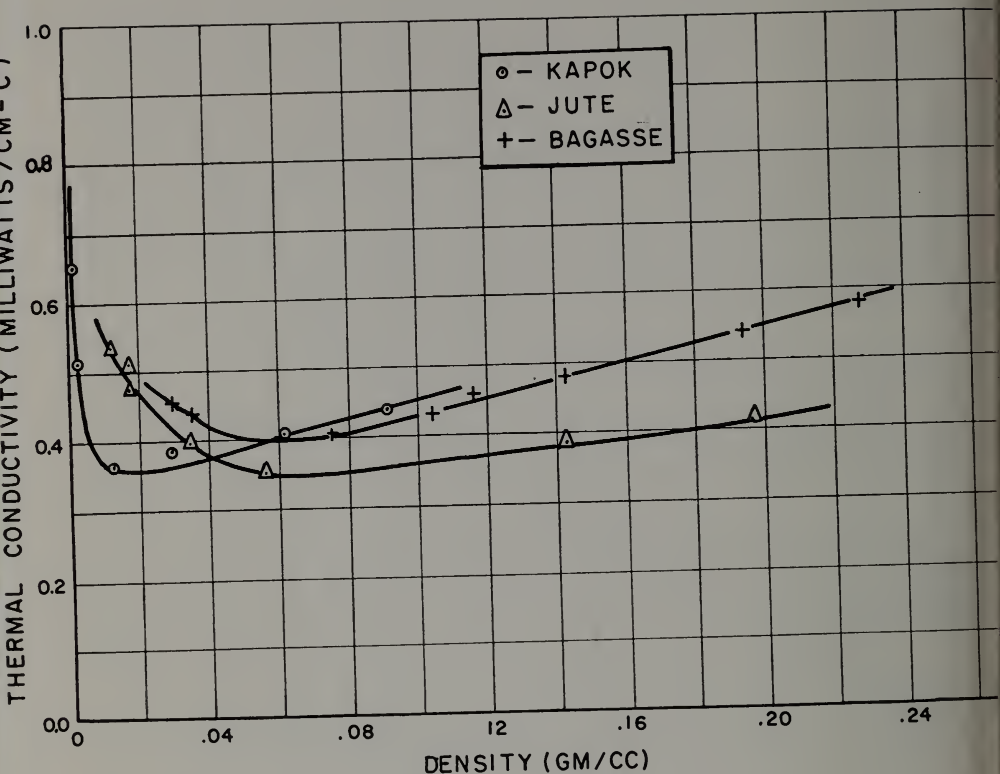

FIGURE 3.—Thermal conductivity for different densities in bone-dry condition. Redrawn from reference (4).

The effect of introducing fibers into the air space on the conduction component is best discussed by referring to Equation [1]. By definition

$$\phi_1 + \phi_2 = 1 \qquad [3]$$

Substituting into Equation [1] the value of y from Equation [2] and ϕ_1 from Equation [3],

$$k_m = x[k_1 + \phi_2(k_2-k_1) - k_1k_2/k_2-\phi_2(k_2-k_1)] + k_1k_2/k_2-\phi_2(k_2-k_1) \qquad [4]$$

The value of x can vary from 0 to 1. The case of x equal to 0 occurs when all the fibers are perpendicular to the direction of heat flow. The case of x equal to 1 occurs when all the fibers are parallel to the direction of heat flow. For fiber arrangements in which the fibers are not wholly parallel or perpendicular to the direction of heat flow, x will have some intermediate value between 0 and 1. Examining Equation [4] and the limiting values for x, the variation of k_m with ϕ_2 can be studied.

Let k' be the value of k when $x = 1$; then from Equation [4],

$$k' = k_1 + \phi_2(k_2-k_1) \qquad [5]$$

This linear function is the line marked k' in Fig. 4.

Let k'' be the value of k_m when $x = 0$; then from Equation [4],

$$k'' = \frac{k_1k_2}{k_2 - \phi_2(k_2-k_1)} \qquad [6]$$

Plotting this function results in the curve marked k'' in Fig. 4.

Equation [4] can now be written in the form

$$k_m = x(k'-k'') + k'' \qquad [7]$$

Equation [7] shows clearly that k_m will vary along some curve lying between k' and k'' for values of x between 0 and 1. The dotted line in Fig. 4 illustrates one possible variation. The curves k' and k'' therefore define the limits within which the conduction component of heat transfer through fibrous aggregates will fall. For fibrous aggregates whose fibers are mostly parallel to the direction of heat flow, the k_m line will approach the line k', while for fibrous aggregates whose fibers are mostly oriented perpendicular to the direction of heat flow, the k_m line will approach the k'' curve.

Considering the combined effects of radiation and conduction, a curve for the air space such as that shown in Fig. 5 can be expected. This assumes that the convection component, as mentioned previously, is negligibly small or nonexistent. When no fibers are present, the total heat flow across the space per unit area per unit temperature gradient has the value k_a and will consist of the thermal conductivity of the air (k_1) and the radiation component of heat transfer. The point k_a will lie on the ordinate which corresponds to a value of ϕ_2 equal to 0. As soon as fibers are introduced, the radiation is cut down while the amount of heat transferred by conduction increases. The latter is due to the substitution of the fibers, which have a higher coefficient of thermal conductivity than air, for air. Since the radiation is decreased more rapidly at low values of ϕ_2 than the conduction is increased, there will be a decrease in the over-all thermal conductivity from its original value of k_a. However, the rise in heat transfer due to conduction, though small at low values of ϕ_2, becomes appreciable as the amount of solid material is increased. The

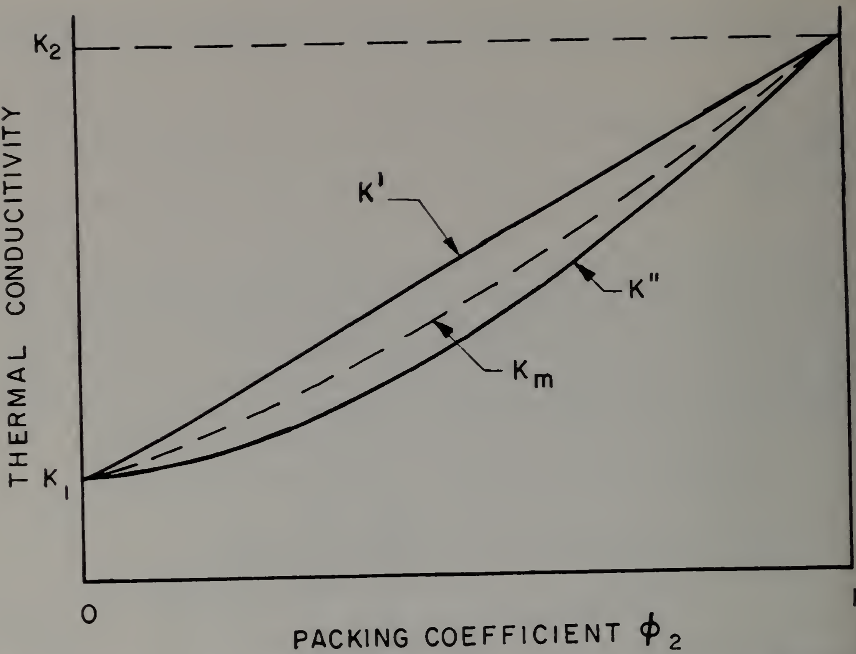

FIGURE 4.—Solid conduction for different fiber orientations vs. packing coefficient in fibrous aggregates.

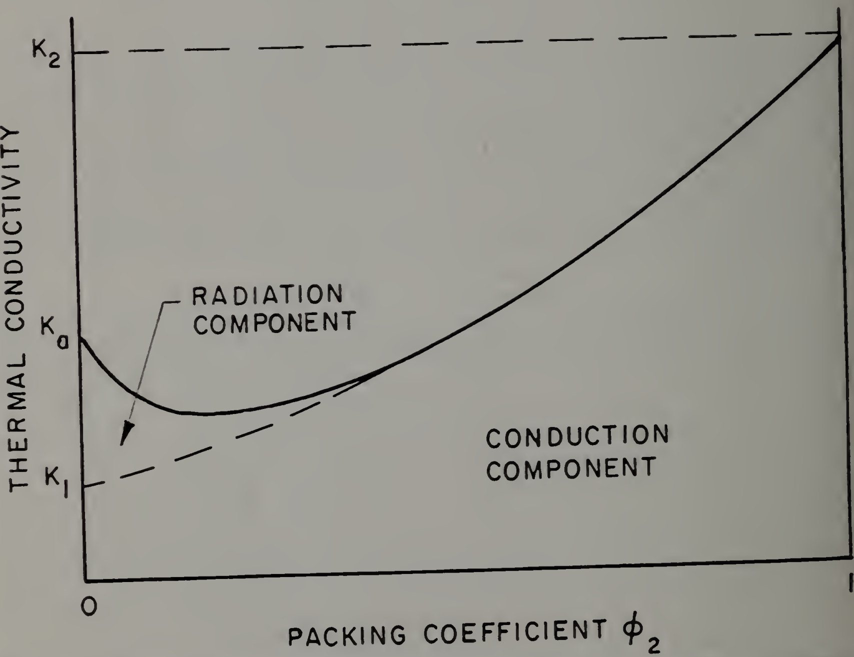

FIGURE 5.—Expected variation of thermal conductivity vs. packing coefficient in fibrous aggregates.

curve of k_m will therefore approach the curve of Schuhmeister's equation and will coincide with it when all radiation is eliminated. When ϕ_2 attains the value of 1, the whole space will be filled with fibers, and the thermal conductivity of this aggregate will then be k_{fiber} or k_2 in Fig. 5.

The preceding discussion shows that for any aggregate of a particular fiber, the value of k'' from Equation [6] will be the lowest possible value of thermal conductivity attainable. The effect of arranging the fibers more parallel to the direction of heat flow is to increase the conduction component to a higher value than k''. Any radiation present will also increase the thermal conductivity of the fibrous aggregate above k''. Thus k'' might be used as a lower limiting thermal conductivity value against which the actual thermal conductivity of a fibrous aggregate can be compared as a measure of the efficiency in using the material for insulation.

It should be understood that the values of k_1 and k_2 used in Equation [4] are both functions of dry-bulb temperature and relative humidity. A comparison between different types of fibers, therefore, should be made only when these values are measured under the same temperature and humidity conditions.

VARIATION OF THERMAL CONDUCTIVITY WITH PACKING COEFFICIENT IN TEXTILES

The thermal conductivities of fabrics should be related to those of cellular materials and fibrous aggregates since textile fabrics have the properties of both these simple forms. The weave of the fabric forms cells, with the yarns making up the walls of the cells. The fibers which make up the yarns impart to the fabric properties which are similar to those of fibrous aggregates.

Close-weave fabrics, like ducks, reduce the open space between the yarns to the point where for all practical purposes the cell spaces are eliminated. Such fabrics can be considered fibrous aggregates with the fibers having some preferred orientation. Generally these fabrics will lie in the range where ϕ_2 is greater than 0.5, and the conduction component of heat transfer will therefore predominate. Open-weave fabrics, on the other hand, will show the effects of radiation and convection, since they will mostly lie in the portion of the $k_m - \phi_2$ curve where ϕ_2 has a value of about 0.2. For fibrous aggregates (Figs. 2 and 3) the optimum value for ϕ_2 was always less than 0.5; the same condition might be expected to hold also for textiles.

Yarn size, twist, and fiber form may also affect the thermal conductivity of the fabric. Large yarns will tend to form larger spaces when woven than smaller yarns. Hard-twist yarns are usually made into fabrics which lie in the portion of the $k_m - \phi_2$ curve where ϕ_2 is closer to 1 than 0. Solid conduction in this region is predominant, and such fabrics would be expected to have higher coefficients of thermal conductivity. Some fabrics may be made of filament yarns which should exhibit greater thermal conductivity values because of the absence of low-density surface regions. Staple fibers, on the other hand, produce a nap or cover which would decrease ϕ_2.

The finishing operations which a fabric undergoes change its form to an extent which may affect its thermal properties. Fulling causes fabric contraction while the thickness is increased. This changes the fiber orientation in the fabric as well as the value of the packing coefficient. Napping produces a region on the surface of the fabric which has a

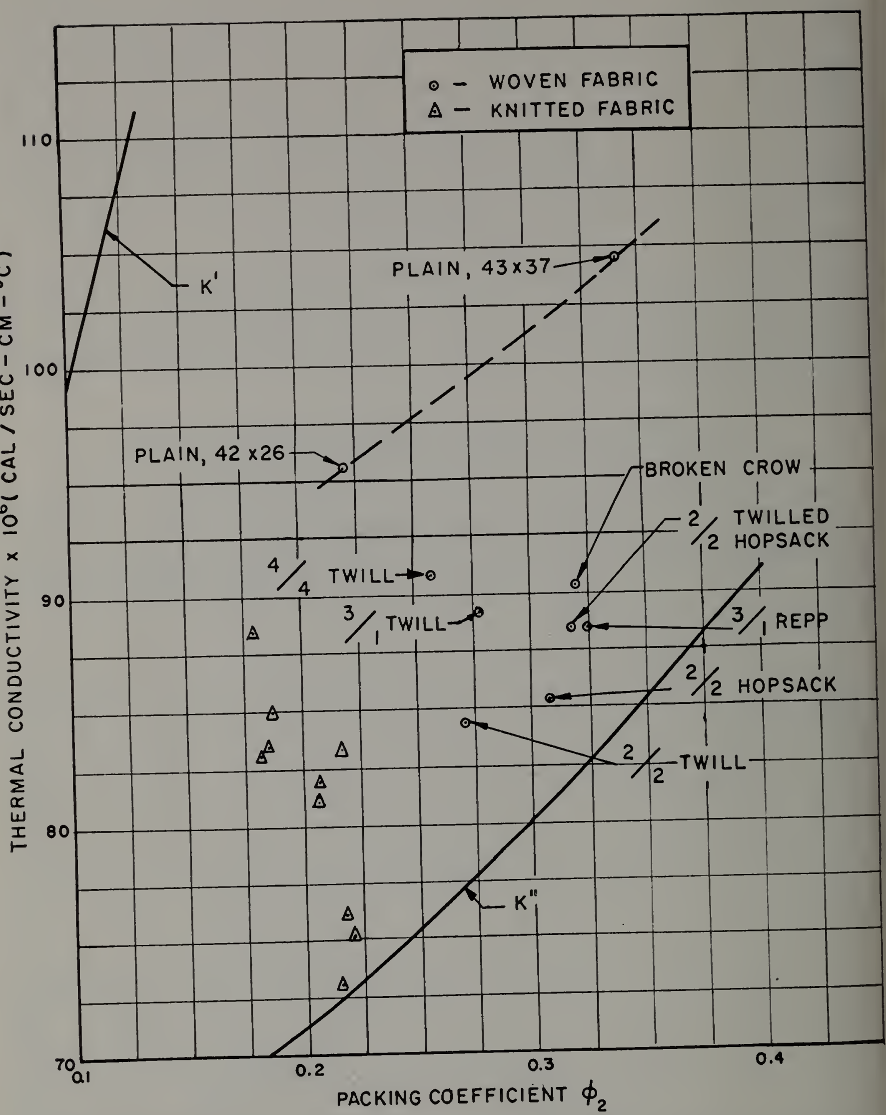

Figure 6.—Thermal conductivity of various knitted and woven wool fabrics as a function of the packing coefficient.

smaller local value for packing coefficient than that beneath the surface of the fabric. The material beneath the surface remains practically the same with regard to fiber orientation and packing coefficient, but its thickness is reduced by the amount of fibers raised in the nap. It can be seen that the local value of packing coefficient varies in passing through the fabric thickness.

From the preceding sections and this discussion it can be concluded that the thermal conductivity is not a unique function of the packing coefficient. Only when the fabrics are made from the same size and type yarn, of the same weave, and when they have undergone the same finishing operations might a single relationship between thermal conductivity and packing coefficient exist.

The equations developed earlier can be used to show the trend of thermal conductivity as a function of ϕ_2 in various fabrics. They also define limits within which this variation can be expected to occur. Figure 6 plots several thermal conductivity values obtained by Speakman and Chamberlain (5) for different woven and knitted wool fabrics. The k'' and k' curves for the conditions under which the data were obtained are also plotted, and k'' might be used as the lower limit for thermal conductivity.

The woven fabrics in general have higher values of ϕ_2 than the knitted fabrics. No direct comparison of their thermal conductivity values, as a measure of their efficiency in using the material as insulation, can be made without first considering what the minimum value of k'' is for the particular value of packing coefficient of each fabric. It is seen that the points for the woven fabrics do not approach the minimum curve k'' as closely as do some of the points for the knitted fabrics. This indicates that knitted fabrics at their best can reduce radiation, convection, and also conduction (due to preferred orientation) more efficiently than woven fabrics of the same material.

The data for the plain-weave fabrics in Fig. 6 are connected with a line, since both fabrics were made from the same yarn and were given the same finishing. This curve shows thermal conductivity increasing with an increase in ϕ_2. It may be seen that the other weaves are more efficient than the plain weave in reducing the conduction, radiation, and convection components of heat transfer, since all of them lie below the curve drawn for plain weave. (The woven fabrics were made from the same yarn and had undergone the same finishing operations.) No conclusions are possible with respect to the comparative efficiencies of the other weaves in Fig. 6 since only single points are shown. However, the data for the 2/2 twill and the 2/2 twill hopsack fall fairly close to the minimum thermal conductivity line, compared to the other weaves, indicating a more efficient use of the material for insulating purposes.

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CURRICULUM BULLETIN

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of the

Lowell Technological Institute of Massachusetts

LOWELL, MASS.

1959-1960

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Textile and Colonial Avenue

EVENING DIVISION

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CALENDAR — 1959-1960

First Semester

September 8, 9, 15, 1959, 7-8:30 P.M.	Registration
September 21, 1959, Monday	Classes begin
October 12, 1959, Monday	Columbus Day, holiday
November 11, 1959, Wednesday	Veterans' Day, holiday
November 25, 26, 27, 1959, Wednesday, Thursday and Friday	Thanksgiving recess
December 21, 1959, Monday	Christmas recess begins
January 4, 1960, Monday	Classes resume
January 15, 1960, Friday	End of first semester

Second Semester

January 12, 13, 14, 1960	Registration
January 25, 1960, Monday	Classes begin
February 22, 1960, Monday	Washington's Birthday, holiday
April 11, 1960, Monday	Easter recess begins
April 20, 1960, Wednesday	Classes resume
May 13, 1960, Friday	End of second semester

FACULTY

CHEMISTRY

Prof. George R. Griffin, B.S., M.A., Ph.D., *Chairman of Division*
Prof. Allen Scattergood, A.B., Ph.D.
Assoc. Prof. Charles L. Daley, B.T.C.
Assoc. Prof. Ernest P. James, B.T.C., M.S.
Assoc. Prof. Roy J. Kuffner, B.S., Ph.D.
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Asst. Prof. Vasilis Lavrakas, B.S., M.S.
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Asst. Prof. Edward L. McCaffery, B.S., M.S., Ph.D.
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Ray E. MacAusland
Robert E. Morrison, B.S.

ENGINEERING

Prof. Charles R. Mingins, A.B., Ph.D., *Chairman of Division*

General Engineering, Electricity, and Electronics

Prof. Charles R. Mingins, A.B., Ph.D., *in charge*
Assoc. Prof. J. Arthur Ainsworth, B.S., M.S.
Assoc. Prof. Andrew A. Ouellette, B.S.
Asst. Prof. Louis C. Block, B.S., Ed.M.
Asst. Prof. Robert K. Devejian, B.S., M.A.
Asst. Prof. Elwyn T. Hook, B.S.
Asst. Prof. Thomas F. McElligott, A.B., Ed.M.
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William E. Dooley, B.S.

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Charles J. Higgins, B.S.

Plastics Engineering

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Asst. Prof Augustus C. Walker, Jr., B.S.
Raymond O. Normandin, A.B., M.S.

Rubber Engineering

Dr. Juan C. Montermoso, B.S., Ph.D.

GENERAL STUDIES

Prof. John R. Robertson, A.B., A.M., *Chairman of Division*

English

Prof. Lester H. Cushing, A.B., Ed.M., *in charge*
Assoc. Prof. John J. MacLaughlan, Ph.B., A.M.
Asst. Prof. Howard K. Moore, A.B., A.M., Ph.D.
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Asst. Prof. J. Frederic Burtt, B.T.E., M.S.
Wilfrid J. Brodeur
George J. Toscano, B.S.

GENERAL INFORMATION

Registration

Students may register by filling out the necessary forms and paying fees before attending classes. Registration is held on the dates indicated in the calendar.

Classes are held on Monday, Tuesday, Wednesday, Thursday, and Friday evenings each week, usually from 7:00 P.M. to 9:00 P.M., although other hours are sometimes required in particular subjects. Classes for those students taking courses toward an Associate Degree will be held from 7:00 P.M. to 9:30 P.M.

The scheduled nights for the various subjects in the following pages are tentative and may be altered in a few cases.

A student must have reached his sixteenth birthday before registering in the Evening Division, unless he has special permission from the Director of the Evening Division.

Late Registration

No new registrations or class changes will be accepted after the first two weeks of classes have been held.

Registration Fee

A registration fee of one dollar per semester is required of all students, in addition to tuition and other charges.

Tuition

Tuition charges for Associate Degree courses will be found on page 8; for Certificate courses, on page 26.

A student cannot take a college-credit subject at the regular rates and then apply for credit at the end of the term.

Employees of Lowell Technological Institute

Employees of the Lowell Technological Institute and its Research Foundation are exempt from all tuition charges.

All tuition and fees must be paid in full at the time of registration.

Laboratory Fees

Students electing any subject that requires laboratory work must pay a laboratory fee of $20 per semester in addition to their tuition. These fees are to cover supplies and normal breakage. Any excessive breakage will be billed directly to the student and must be paid before credit can be obtained. No portion of these laboratory fees will be returned except as provided in the section on refunds. These laboratory fee requirements apply to all students whether they are residents or nonresidents of Lowell and whether they are studying for credit or noncredit.

Refunds

Students dropping out of a class before the end of the first two weeks may obtain a refund of 80% of their tuition and fees. Students dropping out of a class from the second to the fifth week may be refunded 50% of their tuition and fees. There are no refunds after the fifth week of classes. A student must file an application for refund before one can be made. The registration fee of one dollar will not be returned in any case unless the class is cancelled.

Size of Class

No first-year subject will be given unless at least 15 students register for it. In a few instances, more than that number are required. Advanced subjects will usually, but not necessarily, be given regardless of number.

Veterans

All veterans entitled to educational benefits under the law should secure from the V. A. Office a certificate of eligibility before registering.

Books and Supplies

Students must provide their own books, paper, and drawing materials, and pay for any breakage or damage of school equipment that they may cause.

Student supplies will be sold by the school cooperative store each school evening from 6:45 P.M. to 8:15 P.M.

Credits

Subjects considered of college level are indicated in the subject descriptions, and credit hours are assigned to them. A high-school diploma is a prerequisite for all college-level courses.

Transfer Credit

No credit shall be allowed for work done elsewhere which has not been passed with a grade the equivalent of a C (70-79).

No grade for work successfully completed at other institutions shall be considered in computing a student's cumulative rating. Transfer subjects shall be merely recorded with the notation "Cr." When a student requires a record of grades for work done elsewhere, he must obtain an official transcript from the college in question.

Grading System

The following system of grading is used:

A	90 - 100	Excellent
B	80 - 89	Good
C	70 - 79	Fair
D	60 - 69	Lowest Passing Grade
F	50 - 59	Failure
W	Withdrawn	
X	Dropped	

The student's semester rating is a weighted value used to denote his relative standing. The point values assigned are: A = 4 points, B = 3 points, C = 2 points, D = 1 point, and F = 0 points. These point values, when multiplied by the credit hours assigned to the subject and added together, are divided by the sum of the credit hours to give the student's semester rating. The cumulative rating of more than one semester will be obtained in the same manner as the computation for the rating of a single semester.

Please note that no student will be permitted to graduate from the Associate Degree courses with less than a 1.5 cumulative rating.

Information

Address correspondence to Director of Evening Division, Lowell Technological Institute, Lowell, Massachusetts.

ASSOCIATE DEGREE

PROGRAMS OF STUDY

Entrance Requirements

For subjects taken toward an Associate Degree in Engineering the requirement is graduation from a recognized high school or equivalent study or achievement, including one year of algebra.

Conditioned Students

Applicants for the Associate Degree in Engineering who do not meet the full requirements for admission as regular students may, at the discretion of the Committee on Admissions, be admitted as conditioned students provided the secondary-school work completed embraces one unit of algebra.

A conditioned student whose scholarship is satisfactory but who has not removed his conditions within the time specified by the Committee on Admissions may be permitted to continue with his program of studies. However, on the completion of the chosen four-year curriculum he will receive a diploma rather than the Degree of Associate in Engineering.

Students who wish to register for single subjects in the engineering curriculum can do so provided they have the necessary prerequisites.

Tuition

Tuition is at the rate of $10 per credit hour.

Attendance

Students must attend 80% of all classes. Four unexplained absences in a row will result in the student's being automatically dropped from the rolls.

ASSOCIATE DEGREE

First Semester (Sept.-Jan.)

7-9:30 p.m.

NUMBER	SUBJECT	EVENINGS	PREREQUISITE
C-1	General Chemistry	Monday	None
C-1L	General Chemistry Lab.	Wednesday	C-1 concurrently
C-3	Qualitative Analysis	Tuesday	C-2
C-3L	Qualitative Analysis Lab.	Thursday	C-3 concurrently
C-5	Organic Chemistry	Monday	C-2
C-5L	Organic Chemistry Lab.	Wednesday	C-5 concurrently
C-7	Physical Chemistry	Monday	C-4
C-7L	Physical Chemistry Lab.	Wednesday	C-7 concurrently
C-9	Organic High Polymer Chemistry	Tuesday	C-8
C-11	High Polymer Lab.	Not offered 1959-60	C-10
C-15	General Colloid Chemistry	Not offered 1959-60	C-6
E-1	A.C. Machinery Lab.	Monday	E-6
E-3	Advanced Electronic Lab. I	Tuesday or Thursday	E-115 concurrently
E-5	Algebra	To be arranged	E-7 or high-school algebra
E-11	Analytical Geometry & Differential Calculus	To be arranged	E-114
E-15	Applied Leather Analysis	Tuesday	C-6
E-19	Applied Mechanics	To be arranged	E-90, E-114
E-29	D.C. Machinery	Tuesday	E-10
E-31	D.C. Machinery Lab.	Thursday	E-29 concurrently
E-33	D.C. Theory	To be arranged	E-90, E-114
E-37	Electronics for Industry	Thursday	E-6, E-114
E-39	Electronic Physics	To be arranged	E-90
E-41	Electron Tubes	To be arranged	E-10
E-41A	Circuits I	To be arranged	E-41 concurrently
E-45	Engineering Drawing	To be arranged	None
E-53	Heat Engineering	Wednesday	E-90
E-55	Job Evaluation and Merit Rating	Thursday	None
E-57	Leather Technology	Wednesday	C-6
E-59	Leather Technology	Not offered 1959-60	E-56
E-67	Machine Design	Wednesday	E-108
E-69	Machine Drawing	Monday or Wednesday	E-38
E-79	Mechanical Engineering Lab.	Tuesday	E-46
E-81	Mechanism	Thursday	E-68
E-87	Paper Technology	Wednesday	C-6
E-89	Paper Technology	Not offered 1959-60	E-84
E-91	Paper Manufacturing—Testing and Analysis	Thursday	C-6
E-93	Paper Manufacturing—Testing and Analysis	Not offered 1959-60	E-80
E-95	Physical Testing of Leather	Not offered 1959-60	E-54
E-99	Physics	To be arranged	None
E-103	Plastic Technology	Thursday	C-6
E-105	Plastic Technology	Not offered 1959-60	E-92
E-106	Semi-Conductors and Transistors	To be arranged	E-10, E-43
E-115	Communication Engineering	Monday & Wednesday	E-36
E-117	Rubber Technology	Wednesday	C-6
E-119	Rubber Technology	Not offered 1959-60	E-102
E-123	Strength of Materials	Monday	E-18, E-52
E-127	Time Study	Thursday	None
E-131	Properties of Polymers	Not offered 1959-60	C-10

ASSOCIATE DEGREE

Second Semester (Jan.-May)

7-9:30 p.m.

NUMBER	SUBJECT	EVENINGS	PREREQUISITE
C-2	General Chemistry	Monday	C-1
C-2L	General Chemistry Lab.	Wednesday	C-2 concurrently
C-4	Quantitative Analysis	Monday	C-2
C-4L	Quantitative Analysis Lab.	Wednesday	C-4 concurrently
C-6	Organic Chemistry	Monday	C-5
C-6L	Organic Chemistry Lab.	Wednesday	C-6 concurrently
C-8	Physical Chemistry	Monday	C-7
C-8L	Physical Chemistry Lab.	Wednesday	C-8 concurrently
C-10	Physical Chemistry of High Polymers	Tuesday	C-9
C-12	High Polymer Lab.	Not offered 1959-60	C-11
C-16	General Colloid Chemistry	Not offered 1959-60	C-15
E-2	Advanced Electronic Lab. II	Tuesday or Thursday	E-40, E-48 concurrently
E-6	A.C. Machinery	Tuesday	E-29
E-8	A.C. Machinery Lab.	Thursday	E-6 concurrently
E-10	A.C. Theory	To be arranged	E-33
E-18	Applied Mechanics	To be arranged	E-19
E-32	Electronics for Industry Lab.	Thursday	E-37
E-34	Electronic Lab.	Monday or Wednesday	E-36, E-36A
E-36	Electron Tubes	To be arranged	E-41
E-36A	Circuits II	Thursday	E-36 concurrently
E-38	Engineering Drawing	To be arranged	E-45
E-40	Frequency Modulation	Monday	E-115
E-40A	Television	Wednesday	E-40 concurrently
E-44	Electrical Measurements	To be arranged	E-33, E-39
E-46	Heat Engineering	Wednesday	E-53
E-48	Hydraulics	Thursday	E-18
E-52	Integral Calculus	To be arranged	E-11
E-54	Leather Histology	Tuesday	E-15
E-56	Leather Technology	Thursday	E-57
E-58	Leather Technology	Not offered 1959-60	E-59
E-66	Machine Design	Wednesday	E-67
E-68	Machine Drawing	Monday or Wednesday	E-69
E-78	Machine Shop Practice	Wednesday	None
E-80	Paper Manufacturing—Testing and Analysis	Thursday	E-91
E-82	Paper Manufacturing—Testing and Analysis	Not offered 1959-60	E-93
E-84	Paper Technology	Wednesday	E-87
E-86	Paper Technology	Not offered 1959-60	E-89
E-90	Physics	To be arranged	E-99
E-92	Plastic Technology	Thursday	E-103
E-94	Plastic Technology	Not offered 1959-60	E-105
E-96	Principles of Production and Planning	Monday	None
E-100	Research Problems in Leather	Not offered 1959-60	E-95
E-102	Rubber Technology	Thursday	E-117
E-104	Rubber Technology	Not offered 1959-60	E-119
E-108	Strength of Materials	Monday	E-123
E-112	Transmission and Distribution Theory	Tuesday	E-6
E-114	Trigonometry	To be arranged	E-5
E-118	Work Simplification	Thursday	None
E-132	Properties of Polymers	Not offered 1959-60	E-131

CHEMISTRY

Leading to the Degree of Associate in Science

FIRST YEAR

First Semester Course No.	Course	Class Hours	Second Semester Course No.	Course	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-99	Physics I	2½	E-90	Physics II	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chem. Lab.	2½
		7½			7½

THIRD YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
C-7L	Physical Chemistry Lab.	2½	C-8L	Physical Chemistry Lab.	2½
	Elective	2½		Elective	2½
		7½			7½

ELECTRICAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
E-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
E-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
E-33	D.C. Theory	2½	E-10	A.C. Theory	2½
E-19	Applied Mechanics I	2½	E-18	Applied Mechanics II	2½
		7½			7½

THIRD YEAR

E-123	Strength of Materials	2½	E-108	Strength of Materials	2½
E-29	D.C. Machinery	2½	E-6	A.C. Machinery	2½
E-31	D.C. Machinery Lab.	2½	E-8	A.C. Machinery Lab. I	2½
		7½			7½

FOURTH YEAR

E-37	Electronics for Industry	2½	E-112	Transmission Theory	2½
E-53	Heat Engineering	2½	E-46	Heat Engineering	2½
E-1	A.C. Machinery Lab. II	2½	E-32	Electronics for Industry Lab.	2½
		7½			7½

ELECTRONIC ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	COURSE	Class Hours	Second Semester Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
E-45	Engineering Drawing	2½	E-38	Engineering Drawing	2½
E-99	Physics I	2½	E-90	Physics II	2½
		7½			7½

SECOND YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
E-33	D.C. Theory	2½	E-10	A.C. Theory	2½
E-39	Electronic Physics	2½	E-43	Electrical Measurements	2½
		7½			7½

THIRD YEAR

E-41	Electron Tubes	2½	E-36	Electron Tubes	2½
E-41A	Circuits I	2½	E-36A	Circuits II	2½
E-106	Semi-conductors and Transistors	2½	E-34	Electronic Lab.	2½
		7½			7½

FOURTH YEAR

E-115	Communication Engineering	5	E-40	Frequency Modulation	2½
E-3	Advanced Electronic Lab. I	2½	E-40A	Television	2½
			E-2	Advanced Electronic Lab. II	2½
		7½			7½

INDUSTRIAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester

Course No.	COURSE	Class Hours
E-5	Algebra	2½
E-45	Engineering Drawing	2½
E-99	Physics I	2½
		7½

Second Semester

Course No.	COURSE	Class Hours
E-114	Trigonometry	2½
E-38	Engineering Drawing	2½
E-90	Physics II	2½
		7½

SECOND YEAR

Course No.	COURSE	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½
E-19	Applied Mechanics	2½
E-69	Machine Drawing	2½
		7½

Course No.	COURSE	Class Hours
E-52	Integral Calculus	2½
E-18	Applied Mechanics	2½
E-68	Machine Drawing	2½
		7½

THIRD YEAR

Course No.	COURSE	Class Hours
E-123	Strength of Materials	2½
E-55	Job Evaluation and Merit Rating	2½
E-53	Heat Engineering	2½
		7½

Course No.	COURSE	Class Hours
E-108	Strength of Materials	2½
E-118	Work Simplification	2½
E-46	Heat Engineering	2½
		7½

FOURTH YEAR

Course No.	COURSE	Class Hours
E-67	Machine Design	2½
E-127	Time Study	2½
	Engineering Elective	2½
		7½

Course No.	COURSE	Class Hours
E-66	Machine Design	2½
E-96	Principles of Production Planning	2½
	Engineering Elective	2½
		7½

LEATHER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	Course	Class Hours	Second Semester Course No.	Course	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics	2½	E-99	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
E-15	Applied Leather Analysis	2½	E-54	Leather Histology	2½
E-57	Leather Technology	2½	E-56	Leather Technology	2½
		7½			7½

FIFTH YEAR

E-59	Leather Technology	2½	E-58	Leather Technology	2½
E-95	Physical Testing of Leather	2½	E-100	Research Problems in Leather	2½
		5			5

MECHANICAL ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester

Course No.	COURSE	Class Hours
E-5	Algebra	2½
E-45	Engineering Drawing	2½
E-99	Physics I	2½
		7½

Second Semester

Course No.	COURSE	Class Hours
E-114	Trigonometry	2½
E-38	Engineering Drawing	2½
E-90	Physics II	2½
		7½

SECOND YEAR

E-11	Analytical Geometry and Differential Calculus	2½
E-19	Applied Mechanics	2½
E-69	Machine Drawing	2½
		7½

E-52	Integral Calculus	2½
E-18	Applied Mechanics	2½
E-68	Machine Drawing	2½
		7½

THIRD YEAR

E-123	Strength of Materials	2½
E-81	Mechanism	2½
E-53	Heat Engineering	2½
		7½

E-108	Strength of Materials	2½
E-48	Hydraulics	2½
E-46	Heat Engineering	2½
		7½

FOURTH YEAR

E-67	Machine Design	2½
E-79	Mechanical Engineering Lab.	2½
	Engineering Elective	2½
		7½

E-66	Machine Design	2½
E-78	Machine Shop Practice	2½
	Engineering Elective	2½
		7½

PAPER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester Course No.	Course	Class Hours	Second Semester Course No.	Course	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-99	Physics	2½	E-90	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
E-87	Paper Technology	2½	E-84	Paper Technology	2½
E-91	Paper Manufacturing—Testing and Analysis	2½	E-80	Paper Manufacturing—Testing and Analysis	2½
		7½			7½

FIFTH YEAR

Course No.	Course	Class Hours	Course No.	Course	Class Hours
E-89	Paper Technology	2½	E-86	Paper Technology	2½
E-93	Paper Manufacturing—Testing and Analysis	2½	E-82	Paper Manufacturing—Testing and Analysis	2½
C-15	General Colloid Chemistry	2½	C-16	General Colloid Chemistry	2½
		7½			7½

PLASTICS ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester

Course No.	COURSE	Class Hours
E-5	Algebra	2½
C-1	General Chemistry	2½
C-1L	General Chemistry Lab.	2½
		7½

Second Semester

Course No.	COURSE	Class Hours
E-114	Trigonometry	2½
C-2	General Chemistry	2½
C-2L	General Chemistry Lab.	2½
		7½

SECOND YEAR

Course No.	COURSE	Class Hours
E-99	Physics	2½
C-3	Qualitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½
		7½

Course No.	COURSE	Class Hours
E-90	Physics	2½
C-4	Quantitative Chemistry	2½
C-4L	Quantitative Chemistry Lab.	2½
		7½

THIRD YEAR

Course No.	COURSE	Class Hours
E-11	Analytical Geometry and Differential Calculus	2½
C-5	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½
		7½

Course No.	COURSE	Class Hours
E-52	Integral Calculus	2½
C-6	Organic Chemistry	2½
C-6L	Organic Chemistry Lab.	2½
		7½

FOURTH YEAR

Course No.	COURSE	Class Hours
C-7	Physical Chemistry	2½
C-9	Organic High Polymer Chemistry	2½
E-103	Plastic Technology	2½
		7½

Course No.	COURSE	Class Hours
C-8	Physical Chemistry	2½
C-10	Physical Chemistry of High Polymers	2½
E-92	Plastic Technology	2½
		7½

FIFTH YEAR

Course No.	COURSE	Class Hours
C-11	High Polymer Lab.	2½
E-105	Plastic Technology	2½
E-131	Properties of Polymers	2½
		7½

Course No.	COURSE	Class Hours
C-12	High Polymer Lab.	2½
E-94	Plastic Technology	2½
E-132	Properties of Polymers	2½
		7½

RUBBER ENGINEERING

Leading to the Degree of Associate in Engineering

FIRST YEAR

First Semester			Second Semester		
Course No.	COURSE	Class Hours	Course No.	COURSE	Class Hours
E-5	Algebra	2½	E-114	Trigonometry	2½
C-1	General Chemistry	2½	C-2	General Chemistry	2½
C-1L	General Chemistry Lab.	2½	C-2L	General Chemistry Lab.	2½
		7½			7½

SECOND YEAR

E-99	Physics	2½	E-90	Physics	2½
C-3	Qualitative Chemistry	2½	C-4	Quantitative Chemistry	2½
C-3L	Qualitative Chemistry Lab.	2½	C-4L	Quantitative Chemistry Lab.	2½
		7½			7½

THIRD YEAR

E-11	Analytical Geometry and Differential Calculus	2½	E-52	Integral Calculus	2½
C-5	Organic Chemistry	2½	C-6	Organic Chemistry	2½
C-5L	Organic Chemistry Lab.	2½	C-6L	Organic Chemistry Lab.	2½
		7½			7½

FOURTH YEAR

C-7	Physical Chemistry	2½	C-8	Physical Chemistry	2½
C-9	Organic High Polymer Chemistry	2½	C-10	Physical Chemistry of High Polymers	2½
E-117	Rubber Technology	2½	E-102	Rubber Technology	2½
		7½			7½

FIFTH YEAR

C-11	High Polymer Lab.	2½	C-12	High Polymer Lab.	2½
E-119	Rubber Technology	2½	E-104	Rubber Technology	2½
		5			5

ASSOCIATE DEGREE

COURSE DESCRIPTIONS

C-1, C-1L; and C-2, C-2L General Chemistry. Two semesters of basic inorganic chemistry for those with no previous knowledge of chemistry. The fundamental laws of chemistry; the preparation, properties and uses of metals, nonmetals and related compounds; the simple chemical calculations. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 10 credits.

C-3 and C-3L Qualitative Analysis. The systematic analysis of inorganic compounds, carried out by the student in the laboratory using semi-micro technique. Chemical calculations and the balancing of chemical equations are covered in the stoichiometry portion of the course. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 5 credit hours.

C-4 and C-4L Quantitative Analysis. One semester of quantitative analysis for those not desiring college credit in chemistry but who wish to develop laboratory skills and techniques of a practical nature. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 5 credits.

C-5, C-5L; and C-6, C-6L Organic Chemistry. A study of the important classes of carbon compounds and the fundamental theories of organic chemistry. Lecture, 7—9:30 P.M.; laboratory, 7—9:30 P.M. 10 credits.

C-7, C-7L; and C-8, C-8L Physical Chemistry. This subject is designed for those in the laboratory or industry. It includes a discussion of properties of gases, liquids, solids, and solutions; chemical equilibrium, phase equilibrium, thermochemistry, electrochemistry, and other topics according to the need of the students. Laboratory work is assigned as required to give the student practice in the methods and apparatus of physical chemistry. Laboratory work includes the measurement of vapor pressure, viscosity, surface tension, heat of combustion and reaction, conductivity, determination of molecular weight, pH by various methods, etc. One lecture, 7—9:30 P.M., and one laboratory, 7—9:30 P.M., per week. 10 credits.

C-9 and C-10 High-Polymer Chemistry. The chemical structure of high polymers and their manufacture and preparation. The chemical reactions of plastics and their physical properties in relation to their chemical structure. This subject is designed for those in the plastics industry who desire to keep abreast of modern theory or broaden their background. Lecture, 7—9:30 P.M. 5 credits.

C-11 and C-12 See E-92, E-94, E-103, E-105.

C-15 and C-16 General Colloid Chemistry. The basic general principles of colloidal chemistry, followed by elementary analyses of important problems encountered in amorphous materials such as paints, cellulosic products, leather, paper, and textiles. Lecture, 7—9:30 P.M. 5 credits.

E-1 Alternating-Current Machinery Laboratory II. Tests on the single-phase and three-phase induction motors, the brush-shifting motor, investigation of induction motor windings, and tests on the Amplidyne generator. 2½ credits.

E-2 Advanced Electronics Laboratory II. Frequency and phase modulation and demodulation circuits. Video amplifiers, television pulse generators, multivibrators and counters. 2½ credits.

E-3 Advanced Electronics Laboratory I. Audio frequency amplifiers, intermediate frequency amplifiers, mixers, phase inserters, self-excited oscillators,

frequency multipliers. Testing and alignment of complete receivers. Class C radio frequency amplifiers and amplitude modulation methods. 2½ credits.

E-5 Algebra. Fractions, linear and quadratic equations, functions and graphs, systems of equations, determinants, exponents, variation, binomial theorem, theory of equations, and complex numbers. 2½ credits.

E-6 Alternating-Current Machinery. Alternating-current generation, alternator regulation, parallel operation, single-phase and three-phase transformers, vector diagrams, losses and efficiency, polyphase induction motors, torque and speed, power factor, methods of starting, synchronous motors, effect of field excitation and load, power factor correction, single-phase motors, methods of starting, testing of a.c. generators and motors. 2½ credits.

E-8 Alternating-Current Machinery Laboratory I. Measurements of current and voltage in single phase a.c. circuits containing resistance and reactance, power measurement in three-phase circuits, transformer efficiency and regulation, constant-current transformer, efficiency and regulation of alternators, synchronous motors, single-phase motors, characteristics of three-phase induction motors, circle diagram, speed-torque curves, speed control by means of a Thyratron. 2½ credits.

E-10 Alternating Currents. Principles of alternating currents and voltages, impedance, reactance, vector representation, instantaneous and average power, series and parallel circuits, resonance, three-phase circuits, delta and wye-connections, three-phase power. 2½ credits.

E-11 Analytic Geometry & Differential Calculus. Straight line; conic sections; differentiation of algebraic, trigonometric, logarithmic, and exponential functions; differentials; rates; slopes of curves; maxima and minima. 2½ credits.

E-15 Applied Leather Analysis. A subject designed to acquaint the student with the accepted methods of analysis of the American Leather Chemists Association and other supplementary procedures. 2½ credits.

E-18 and E-19 Applied Mechanics. The fundamentals of statics, including such topics as force systems, laws of equilibrium, friction, centers of gravity, moments of inertia, stress fundamentals, strain, bending moment and deflection. 5 credits.

E-29 Direct-Current Machinery. Generator principles, armature and field windings, types of generators, armature reaction, compensation, characteristics of shunt and compound generators, amplidyne, motor principles, shunt motor, series motor, compound motor, motor controllers and starters, motor testing, applications of d.c. generators and motors. 2½ credits.

E-31 Direct-Current Machinery Laboratory. Direct-current generator connections, compound generators, parallel operation of generators, efficiency measurements, starting rheostats for d.c. motors, shunt-motor characteristics, series motors, compound motors, efficiency of d.c. motors, determination of stray power losses, operation of balancer set, dynamotor. 2½ credits.

E-32 Electronics for Industry Laboratory. Characteristics of high-vacuum triodes, thyratron characteristics, grid-control methods, control by phase shifting, resistance-welding controls, synchronous timing, thyratron photoelectric relay, heating and lighting controls, speed and voltage regulators for d.c. motors and generators, polyphase rectifiers, saturable reactors, ignition rectifier. 2½ credits.

E-33 Direct Currents. Units of current, resistance and voltage, resistance of wires, temperature coefficient, series circuits, parallel circuits, Ohm's law and

Kirchoff's law, energy and power, Thevenin's theorem, magnetic fields and lines of force, magnetic fields produced by electric currents, electromagnets, d.c. ammeters and voltmeters, the electric field, properties of dielectrics. 2½ credits.

E-34 Electronic Laboratory. Electron dynamics, thermionic emission, characteristics of vacuum and gas diodes, triodes. Equivalent circuits for tubes, voltage and power amplifiers. Photo-cells, cathode ray oscilloscopes, impedance bridge and vacuum tube voltmeters. (Must be taken concurrently with E-36.) 2½ credits.

E-36 and E-36A Electron Tubes and Circuits II. Vacuum tube amplifiers of all classes; distortion; coupling methods; inverse feedback in amplifiers. 5 credits.

E-37 Electronics for Industry. Single and polyphase rectification and filtering. Basic electron tubes; voltage and current stabilization circuits; thyratron and photo-tube control circuits and applications. 2½ credits.

E-38 and E-45 Engineering Drawing. Freehand and mechanical drawing, including lettering, geometric construction, orthographic projection, isometric and cabinet drawing, and dimensions, auxiliary views, cross sections, advanced dimensioning, sketching of machine parts, working drawings, tracing and blueprinting, intersections, and developments. 5 credits.

E-39 Electronic Physics. Introductory field theory applied to propagation in free space, dielectrics, and conductors. Reflection and refraction of waves; interference, diffraction, and polarization. Transmission lines; antennas; impedance matching. Properties of the ionosphere. 2½ credits.

E-40 and E-40A Frequency Modulation and Television. Principles of conveying electronic visual information by wire, radio photo, facsimile, and television. Television systems: generation transmission and reception of television signals. 5 credits.

E-41 and E-41A Electron Tubes and Circuits I. Electron dynamics, thermionic emission, secondary emission, field emission, and photo-electric emission. Mechanical design consideration of radio tubes. Tube characteristics and coefficients. The application of radio tubes to amplifier circuits and rectifiers. 5 credits.

E-44 Electrical Measurements. Measurements of resistance, capacitance, inductance, impedance, voltage, current, and power. D.c. and a.c. bridge circuits, magnetic measurements, frequency and phase measurements. 2½ credits.

E-46 and E-53 Heat Engineering. The basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A brief treatment of steam engines, turbines and pumps. Special consideration is given to the use of steam in manufacturing processes. 5 credits.

E-48 Hydraulics. Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs; orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids, Mach's number; dynamical similitude and Pi theorem. 2½ credits.

E-52 Integral Calculus. Indefinite and definite integrals; areas; length of curves; area of surface of revolution; volumes of solids of revolution; integration of trigonometric, logarithmic, and exponential functions; methods of integration. 2½ credits.

E-54 Leather Histology. A study of the structures of animal skin and of the changes which they undergo in the leathermaking process. Because the basically extracellular nature of skin demands it, considerable time is devoted to the nature and function of the fundamental protein constituents. 2½ credits.

E-55 Job Evaluation and Merit Rating. Covers the principles and practices in the analysis of the job and the worker's performance on that job. Specific subjects covered include job description, determining job factors and translating these into rating values, wage calculations and wage structures. 2½ credits.

E-56, E-57, E-58, E-59 Leather Technology. Introduction to the technology of leather manufacture. The first two semesters are devoted to examining government regulations in imported hides and skins, studying the purchasing of hides and skins, and classifying various hide damages. This is followed by work on the handling of raw stock at the tannery, unhairing, bating, and hide classification. The third and fourth semesters are concerned primarily with the study of vegetable tanning, chrome tanning, and various other types of tanning. In the work throughout the year the material covered in lectures is supplemented by laboratory studies on a small scale. 10 credits.

E-66 and E-67 Machine Design. The design of machine elements, such as fasteners, shafts, frames, bearings, gears, clutches, springs, keys and drives. Data for most of the problems are taken from actual machines in the various laboratories. 5 credits.

E-68 and E-69 Machine Drawing. Several short problems involving centers of gravity, counterweights, cam layouts, piping, welding, sheet metal drafting, and assembly drawings. 5 credits.

E-78 See E-63, p. 29. 2½ credits.

E-79 Mechanical Engineering Laboratory. Fundamentals of engineering measurements, flow measurement of steam and air, tests of steam turbine and internal-combustion engine, experimental work with refrigeration units, measurements of heat transfer, combustion, fluid flow, performance of pumps, and testing of engineering material. 2½ credits.

E-80, E-82, E-91, E-93 Paper Manufacturing — Testing and Analysis. An elementary study of the fundamental processing techniques used in paper manufacture. The lecture work is accompanied by laboratory training in papermaking, paper testing and analysis, and paper microscopy. 10 credits.

E-81 Mechanism. The basic principles of kinematics, in which the wide variety of process machinery available furnishes many specific examples. Frequent use of these mechanisms is made in the development of the subject. Some of the important topics covered are the following: rolling cylinders and cones, gearing, gear train design, epicyclic gear trains, flexible connectors including stepped pulley and cone design, cam design, linkages, and miscellaneous mechanisms. 2½ credits.

E-84, E-86, E-87, E-89 Paper Technology. Lectures on the production and technology of pulp and paper. 10 credits.

E-90 and E-99 Physics. The fundamentals of mechanics, heat, sound, electricity, and light. The first-semester topics include force systems, energy and power, motion, liquids and gases, calorimetry and thermodynamics. The second-semester topics include wave motion, sound phenomena, magnetism, electrostatics, d.c. and a.c. circuits, reflection and refraction of light, lenses, optical instruments, physical optics, and elements of atomic physics. 5 credits.

E-92 and E-103 Plastic Technology. This is an introductory study of plastics. It includes history, classification, properties, definitions, and uses. Raw materials, methods of manufacturing, processing, and fabrication. Lectures and laboratory. 5 credits.

E-94 and E-105 Plastic Technology. Additional instruction in processing and fabrication. Applications of plastics, engineering properties, equipment, mold and product design. Testing of plastics. Lectures and laboratory. 5 credits.

E-95 Physical Testing of Leather. A practical and theoretical study of the characteristics of leather in relation to the end use. Studies are made on measuring and classifying the effect of changes in manufacturing procedure, both chemical and physical. Leather, because it is a natural product, varies considerably within the same hide. Thus the nature of this variation is very important, and the study of any changes affecting it is, in turn, important. 2½ credits.

E-96 Principles of Production Planning. The student is introduced to the processes followed in planning from the original idea of the product to the shipment of the finished product from the plant. Among the topics covered are product analysis, plant location and layout, organization, budgeting, and control. 2½ credits.

E-100 Research Problems in Leather. This subject is designed primarily to enable the student to apply the various scientific principles of physics, chemistry, mathematics, economics, etc., to problems of an industrial nature. This may encompass anything from the design and layout of a special leather plant to the suggested solution of practical problems which arise in the operation of a modern business. 2½ credits.

E-102 and E-117 Fundamentals of Rubber Technology. An introductory course for those who wish to acquire a general knowledge of rubber technology. Physical properties, composition, compounding, vulcanization, evaluation, deterioration, etc., of various types of synthetic rubbers and natural rubber. Lectures and laboratory. 5 credits.

E-104 and E-119 Advanced Rubber Chemistry and Technology. Monomers; polymerization systems; relation of chemical structure to physical properties; theories of vulcanization, acceleration, reinforcement, and deterioration of elastomers. Lectures and demonstrations. 5 credits.

E-106 Semiconductors and Transistors. An introduction to solid state electronics. Crystal diodes transistors: their operation and applications. 2½ credits.

E-108 and E-123 Strength of Materials. This subject covers such topics as beams, beam design, torsion, columns, combined stresses, reversals of stress and impact. Includes such topics as bending and shearing stresses, torsion, compound beams and columns, reversals of stress, impact, vibrations, stress analysis by strain gage methods, concepts of creep and relaxation. 5 credits.

E-112 Transmission and Distribution of Power. Transmission systems, reactance, capacitance, three-phase line calculations, corona power, lightning arresters, transmission structures, transformer substations, distribution circuits, automatic substations. 2½ credits.

E-114 Trigonometry. Trigonometric functions, identities, reference angles, radians, multiple angles, trigonometric equations, logarithms, slide rule, right triangles, and oblique triangles. 2½ credits.

E-115 Communication Engineering. Theory and applications of thermionic tubes and transistors in amplifiers, oscillators, modulators, and detectors. Selectivity, sensitivity, stability of radio receivers and transmitters. 5 credits.

E-118 Work Simplification. The study of cost reduction through the analysis of the job, plant layout, tools and equipment, and of worker activity through the use of process, flow, operation, man and machine charts and the principles and practices of motion study. 2½ credits.

E-127 Time Study. The methods and rules of time study. A brief historical background is given before the student is introduced to the techniques of making time studies. Specific points covered include job standards, use of allowances, treatment of variables, use of data, "normal performance", and rating procedures. 2½ credits.

E-131 and E-132 Properties of Polymers. This subject includes the study of important engineering properties of plastics materials; theory of testing; the examination of testing techniques, equipment, and standard ASTM methods for evaluating mechanical, thermal, electrical, and optical properties. 5 credits.

CERTIFICATE COURSES

PROGRAM

Entrance Requirements

For subjects taken toward a certificate the requirement, in general, is graduation from grammar school or equivalent education.

Tuition for subjects not offering college credit or credit toward an Associate Degree is free to Lowell Technological Institute day students and residents of Lowell, but nonresidents will be charged as follows:

Evenings Per Week	*Hours Per Evening*	*Tuition*
1	2	$ 5.00
1	2½	6.25
1	3	7.50
2	2	10.00
2	2½	12.50
2	3	15.00
3	2	15.00
3	2½	18.75
3	3	22.50

All tuition and fees must be paid in full at the time of registration.

To receive free tuition, residents of Lowell must file a certificate of residence with the Registrar. These certificates may be obtained from the Election Commission, City Hall, Lowell. However, registration may be completed prior to filing the certificate.

Size of Class

No first-year subject will be given unless at least 15 students register for it. In a few instances, more than that number are required. Advanced subjects will usually, but not necessarily, be given regardless of number.

Attendance

Students must attend 70% of classes held in order to receive a certificate for the subject. Four unexplained absences in a row will result in the student's being automatically dropped from the rolls.

College Credit

A few of the certificate courses are given on the college level and carry college credit. They are so indicated on the course listings and subject descriptions. For these courses the tuition fees for college-credit courses, as shown on page 8, apply.

CERTIFICATE COURSES

FIRST SEMESTER (SEPT.-JAN.)

7-9:00 P.M.

NUMBER	SUBJECT	EVENINGS	PREREQUISITE
C-52	Organic Chemistry for the Medical and Biological Sciences (4 credits)	To be arranged	Permission of instructor
E-7	Algebra	Monday or Wednesday	None
E-9	Algebra	Monday or Wednesday	E-7
E-17	Applied Mathematics	Monday and Wednesday	None
E-25	Blueprint Reading	Monday and Wednesday	None
E-49	Fundamentals of Plastics	Monday	None
E-61	Leather Technology	Tuesday and Thursday	None
E-63	Machine Shop Practice	Monday or Wednesday	None
E-65	Machine Shop Practice	Thursday	E-63
E-71	Mechanical Drawing	Monday or Wednesday	None
E-73	Mechanical Drawing	Tuesday or Thursday	E-71
E-75	Mechanical Drawing	Tuesday or Thursday	E-73
E-77	Mechanical Drawing	Tuesday	E-75
E-77A	Mechanical Drawing	Wednesday	E-77
E-97	Physics	Monday or Wednesday	E-7 or high-school algebra
E-107	Pulp Technology	Tuesday	None
E-111	Statistical Quality Control	Monday and Thursday	None
E-129	Trigonometry	Tuesday or Thursday	E-7 or high-school algebra
E-133	Mathematics of Finance	Tuesday	None
G-1	Accounting I	Monday and Thursday	None
G-3	Accounting III	Tuesday and Thursday	G-2
G-5	Accounting V	Monday and Wednesday	G-4
G-15	English Composition	Tuesday	None
G-25	Literature I (3 credits)	Monday	1 year college English
G-27	Communications and Human Relations (2½ credits)	Tuesday	None
G-31	Main Currents in Modern Drama (3 credits)	Tuesday	1 year college English
G-47	Vocabulary Building	Monday and Wednesday	None
GS-371	American Civilization (3 credits)	Wednesday	1 year college English
GS-469	International Relations (3 credits)	Thursday	None
MA-206	Differential Equations (3 credits)	Tuesday and Thursday	MA-205
MA-301	Advanced Calculus (3 credits)	Tuesday and Thursday	MA-206

CERTIFICATE COURSES

SECOND SEMESTER (JAN.-MAY)

7-9:00 P.M.

NUMBER	SUBJECT	EVENINGS	PREREQUISITE
C-52A	Inorganic Chemistry for the Medical and Biological Sciences (4 credits)	To be arranged	Permission of instructor
E-4	Paper Technology	Tuesday	E-107
E-7	Algebra	Monday or Wednesday	None
E-9	Algebra	Monday or Wednesday	E-7
E-17A	Applied Mathematics	Monday and Wednesday	None
E-24	Blueprint Reading	Monday and Wednesday	None
E-60	Leather Technology	Tuesday and Thursday	E-61
E-63	Machine Shop Practice	Monday or Tuesday	None
E-65	Machine Shop Practice	Thursday	E-63
E-71	Mechanical Drawing	Monday or Wednesday	None
E-73	Mechanical Drawing	Tuesday or Thursday	E-71
E-75	Mechanical Drawing	Tuesday or Thursday	E-73
E-77	Mechanical Drawing	Tuesday	E-75
E-77A	Mechanical Drawing	Wednesday	E-77
E-77B	Mechanical Drawing	Thursday	E-77A
E-97	Physics	Monday or Wednesday	E-7 or high-school algebra
E-111A	Advanced Quality Control	Thursday	E-111
E-129	Trigonometry	Tuesday or Thursday	E-7 or high-school algebra
G-2	Accounting II	Monday and Thursday	G-1
G-4	Accounting IV	Tuesday and Thursday	G-3
G-6	Accounting VI	Monday and Wednesday	G-5
G-8	Literature II (3 credits)	Monday	1 year college English
G-16	English Composition	Tuesday	G-15
G-26	Meaning and Use of Words	Monday and Wednesday	None
MA-206	Differential Equations (3 credits)	Tuesday and Thursday	MA-205
MA-302	Advanced Calculus (3 credits)	Tuesday and Thursday	MA-301

CERTIFICATE
COURSE DESCRIPTIONS

C-52A Inorganic Chemistry for the Medical and Biological Sciences. One semester of inorganic chemistry oriented for those working in the medical and biological sciences. The basic tenets of chemistry are surveyed in lecture and laboratory. Four hours of lecture and 2 hours of laboratory. 4 credits.

C-52 Organic Chemistry for the Medical and Biological Sciences. A one-semester survey course of the fundamentals of organic and biological chemistry. The aliphatics, aromatics, carbohydrates, fats, proteins, digestion, and metabolism are discussed. Two hours of lecture and 4 hours of laboratory. 4 credits.

E-4 Paper Technology. Details of manufacture of paper, including stock preparation, filling, sizing, coloring, chemical additives, and paper machine operation.

E-7 Algebra. Algebra, including addition, multiplication, subtraction, division, factoring, and fractions.

E-9 Algebra. A continuation of E-7. Some of the topics treated are: graphical representation, linear equations, radicals, quadratic equations, logarithms, slide rule, and some trigonometry.

E-17 and E-17A Applied Mathematics. Designed for students who need a review of the fundamental processes and includes some plane and solid geometry, algebra, logarithms, and trigonometry. Use of the slide rule is stressed in the solution of practical problems.

E-24 Blueprint Reading. Similar to E-25, but with emphasis on architectural, rather than engineering, blueprints.

E-25 Blueprint Reading. The principles of mechanical drawing, *e.g.*, projections, sections, dimensioning, etc., necessary for the understanding of blueprints.

E-49 Fundamentals of Plastics. An introductory study for those who wish to acquire a general knowledge of plastics. Classification, description, chemical and physical properties, uses, and methods of fabrication.

E-60 and E-61 Leather Technology. The theoretical aspects of leather production coupled with a laboratory to carry out the planning of process control, material control, and product quality control. One section will be devoted to an intensive introduction to the histology of hides and skins and histological preparations.

E-63 and E-65 Machine Shop Practice. Metal-working, including bench work, lathes, grinders, planers, shapers, presses, milling machines, care of tools, tool grinding, heat treatment, forging and use of special tools. The classes are limited to 25 students.

E-71, E-73, E-75, E-77, E-77A, E-77B Mechanical Drawing. Fundamentals of engineering drawing. The first semester covers lettering, use of instruments, geometric construction, orthographic projection, multi-view and pictorial free-hand drawing. The second semester includes dimensioning, auxiliary views, cross-sectioning, screw threads and working drawings. The third semester offers intersections, pictorial drawings, and applications to sheet metal drawings. The fourth semester covers assembly drawings from details of parts and detailing from designers' assembly drawings.

E-97 Physics. Elementary physics on the high-school level. Lectures and demonstrations.

E-107 Pulp Technology. The basic principles of manufacture of the common papermaking pulps and the bleaching processes.

E-111 Statistical Quality Control. This course starts off with instruction in the basic statistical concepts needed to understand and use the tools of quality control. It then proceeds to introduce and illustrate some of these "statistical tools." Subjects covered are: measures of central tendency and dispersion, normal curve analysis, simple process capability studies, basic control charts for measurable and nonmeasurable characteristics, acceptance sampling techniques and determination of tolerances. The emphasis is placed on the practical rather than the mathematical approach to quality problems. Case studies, audio-visual aids, and practical demonstrations are used to supplement the lectures.

E-111A Advanced Quality Control. This course will deal with some of the more advanced methods developed to aid in the solution of quality problems in industry. Techniques of process analysis and process control such as the Span Plan, modified control limits, Narrow Limit Gaging, and Pre-Control will be introduced and illustrated. Tests of significance such as: the X^2 test, the "t" test, the "F" test, and some nonparametric tests will be discussed. The course will also spend some time acquainting the student with some of the practical aspects of organization, administration, and economics of a quality control program.

E-129 Trigonometry. The solution of all triangles by both natural and logarithmic functions, identities, radian measure, principal values and the solution of trigonometric equations.

E-133 Mathematics of Finance. Simple interest and simple discount, compound interests, annuities, amortization including amortization of bonds and life insurance and annuities.

MA-206 Differential Equations. A review of series and partial differentiation, first- and second-order differential equations, and first- and second-order partial differential equations. Practical applications for the chemist and the engineer. 3 credits.

MA-301-302 Advanced Calculus. Ordinary differential equations, Laplace transformation, numerical methods of solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations, partial differential equations of mathematical physics, and complex variable theory. 6 credits.

G-1 and G-2 Accounting I and Accounting II. The principles of accounting. The balance sheet and income statement, the theory of debits and credits, special journals, controlling accounts and subsidiary ledgers are covered in the first semester. The second semester carries the student into payroll and tax accounting, partnership and corporate records, the basic principles of manufacturing accounting, and the interpretation of the statements of financial condition.

G-3 and G-4 Intermediate Accounting. The two semesters include the accounting statements, the recording process, the periodic summary, working capital, receivables, inventories, plant and equipment, intangible assets, deferred charges, long-term debt, deferred credits, capital stock, surplus, preparation of statements, statement analysis, and application of funds.

G-5 and G-6 Advanced Accounting. This two-semester course prepares specifically for C.P.A. examinations and covers accounting for partnerships, special

sales procedures, consolidations, foreign exchange, fiduciaries, governmental units, and actuarial science.

G-8 *Literature II.* This course aims to develop standards of literary criticism and to familiarize the student with six or more classics of western civilization. Lectures, class discussion, and critical papers form the basis of class meetings. College level; 3 credits.

G-15 *English Composition.* The basic elements of composition, including remedial English, grammar, sentence structure, etc.

G-16 *English Composition.* Writing for business and social purposes. Narration, description, reports, letters, etc.

G-25 *Literature I.* Attention is focused on six or seven major writers. Emphasis will be on discovering what these authors have to say that is of interest or importance to the general reader today. The student will have the opportunity to determine the attitude toward life of each writer, to see what gave rise to this attitude, and to evaluate it and compare it with the views of other writers considered in the course. College level; 3 credits.

G-26 *The Meaning and Use of Words.* The exact meaning of words and how their proper usage can lead to clear and dynamic speech.

G-27 *Communications and Human Relations.* Problems of communication in business and industry, in management training, and in foreman supervision. Personnel practices in plant supervision and management. Case histories in company programs of executive development training. Communication difficulties are discussed and remedies offered for solution. 2½ credits.

G-31 *Main Currents in Modern Drama.* The purpose of the course is to impart an intelligent and enthusiastic interest in the theater of the Twentieth Century. Significant plays by Ibsen, Strindberg, Chekhov, Shaw, O'Neill, Miller, and Williams will be discussed. 3 credits.

G-47 *Vocabulary Building.* A subject to help the student enlarge his vocabulary and improve his understanding and choice of words. Language roots and word evolution are also studied.

GS-371 *American Civilization.* The beginnings of a national consciousness viewed from the aspects of the cultural, economic, and social evolution of the American people. The way of life of a growing democracy—its methods of livelihood, its arts, its industries, its literature. 3 credits.

GS-469 *International Relations.* A symposium on the problems of the world community in transition with emphasis on Post World War II relationships. Realities in foreign policy and geopolitical theories. Foreign policies of key nation-states. The effect of nuclear weapons on foreign policy. Distinguished guests contribute their viewpoints to the discussions. 3 credits.

LOWELL TECHNOLOGICAL INSTITUTE

CATALOGUE ISSUE

1959-1960

Special SCIENCE COUNT-DOWN Edition

The Board of Trustees of the Lowell Technological Institute voted to publish this special SCIENCE COUNT-DOWN edition of the college catalogue as an integral part of its program of scientific and technological education. The SCIENCE COUNT-DOWN 1959 project has been sponsored by the Institute for the purpose of stimulating an awareness among the young people and parents of the Commonwealth of the importance of a knowledge of the basic sciences. In cooperation with WBZ-TV, Boston, the Institute inaugurated in February, 1959, a state-wide science quiz for all students in the eighth grades of public, parochial, and private schools. After the elimination contests, the pupils selected as county winners appeared in a weekly series of live telecasts culminating in a grand final "count-down," which, in effect, resulted in the selection of the outstanding "junior scientist" in the Commonwealth of Massachusetts. The Trustees feel that this pioneering project in the field of education has great potentialities for enhancing the intellectual curiosity of the young people of the state with especial reference to the field of science, and they trust that, through this Bulletin made available for general distribution, the beneficent effect of SCIENCE COUNT-DOWN 1959 may be extended indefinitely.

Aerial View of the Campus

Reading Room of the Library

Series 63, No. 1 August, 1959

BULLETIN

of the

Lowell Technological Institute

LOWELL, MASS.

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1959

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The Institute reserves the right to make changes in the regulations, courses, and charges announced in this Bulletin.

INSTITUTE CALENDAR FOR ACADEMIC YEAR 1959-1960

September 8, Tuesday	Freshman Orientation Week begins.
September 14, Monday	Registration of seniors and juniors.
September 15, Tuesday	Registration of sophomores and graduate students.
September 16, Wednesday	Classes begin.
September 23, Wednesday	Last day to register for new classes.
October 12, Monday	Columbus Day. Institute closed.
October 13, Tuesday	Last day to drop classes without penalty.
November 11, Wednesday	Veterans' Day. Institute closed.
November 25, Wednesday, 1 P.M.	Thanksgiving recess begins.
November 30, Monday	Classes resume.
December 18, Friday, 5 P.M.	Christmas recess begins.
January 4, Monday	Classes resume.
January 11, Monday	First-semester examinations begin.
January 23, Saturday	First-semester examinations end.
February 1, Monday and February 2, Tuesday	Registration of all students.
February 3, Wednesday	Classes begin.
February 10, Wednesday	Last day to register for new classes.
February 22, Monday	Washington's Birthday. Institute closed.
March 1, Tuesday	Last day to drop classes without penalty.
April 8, Friday, 5 P.M.	Easter recess begins.
April 20, Wednesday	Classes resume.
May 18, Wednesday	Second-semester examinations begin.
June 3, Friday	Second-semester examinations end.
June 5, Sunday	Baccalaureate and Commencement.

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Jane M. Teague	*Office of Admissions*

Buildings and Power

George F. Abodeely, LL.B.	*Administrator*
Ralph E. Frost	*Chief Engineer*
Joseph A. Nerney	*Maintenance Foreman*

ALUMNI ASSOCIATION

Objectives of the Alumni Association are to advance the interests of Lowell Technological Institute, to secure systematic and unlimited gifts thereto and to receive and hold money and property, both real and personal, and to manage, use, and dispose of the same as appears to be in the best interests of the Institute.

All students of the Institute who have completed satisfactorily at least one year of the day curriculum are eligible for active membership. Only the active members have the right to vote and hold office in the Association.

The by-laws of the Association also provide for Honorary and Associate memberships. The Honorary Membership, Scroll, and Citation may be awarded by the Board of Directors to any person who has made outstanding contribution to the arts or sciences. Any person not otherwise eligible for membership who has made significant contribution to the welfare of the Institute may be elected to Associate membership by the Board of Directors. The Honorary Award, Scroll, and Citation may be awarded by the Board of Directors to any active member of the Alumni Association who has made outstanding contribution to the arts or sciences.

The Association administers numerous scholarships and fellowships; publishes the official alumni magazine, "The L.T.I. Alumni Bulletin"; publishes an Alumni Directory; aids student organizations; and performs the numerous functions normally associated with alumni organizations. Membership is held in the American Alumni Council. The Association holds its annual business meeting and banquet in the spring of each year.

Communications should be addressed to Professor A. Edwin Wells, Executive Secretary, Alumni Office, Lowell Technological Institute.

Officers

Clifford A. Harvey, '49, *President*

Harold L. Peckham, '17, *First Vice President*

Herbert W. Wilkinson, '37, *Second Vice President*

A. Edwin Wells, '20, *Clerk, Treasurer, and Executive Secretary*

Robert E. Morrison, '51, *Assistant Secretary*

Eugene F. Crane, '33, *Chairman of the Fund Council*

RESEARCH FOUNDATION

In recognition of the unique research opportunities afforded to industry by virtue of the equipment and staff available at Lowell Technological Institute, the Massachusetts State Legislature in November, 1950, authorized the establishment of the Lowell Technological Institute Research Foundation. Its purpose is to conduct research, development, and consulting programs under contract with responsible agencies and industrial organizations. This activity has the effect of permitting staff members access to new and significant developments in industry and materially assists in keeping the teaching programs current and dynamic.

The Research Foundation provides the necessary mechanism whereby all of the research work of the Institute is brought under one coordinating office headed by the Executive Director. As in the past, however, the faculty of the Institute does the greater part of the research work. This plan has been proved through years of experience to be highly beneficial to the Commonwealth, to the Institute and to industry.

The Foundation has the use of the Institute's laboratory and research facilities in chemistry, physics, engineering, textiles, electronics, paper, leather, and plastics. The Institute has many unusual research facilities. These include a completely equipped laboratory for work with radioactive materials, an Instron tester, X-ray diffraction equipment, a large spectograph, recording spectrophotometers, a pulse-propagation meter, and a completely equipped laboratory for microscopic work including phase microscopy and electron microscopy.

It is probably the only research organization in the world having at its disposal fully equipped laboratories to manufacture and finish nearly all types of fibers by all the common manufacturing systems as well as similar equipment for paper, leather, and plastics processing. These splendidly equipped laboratories serve as pilot plants for the evaluation of industrial and manufacturing problems submitted to the Foundation.

The Foundation organization is built around the three basic divisions of research, development, and testing, and is currently active in all three fields for both governmental agencies and industrial organizations. The Foundation also is of benefit to the educational program of the Institute by enabling both graduate students and faculty members to engage in research projects with a mutual instructional value.

For further information and descriptive literature about the Research Foundation, write to Mr. Dorrance H. Goodwin, Executive Director, Lowell Technological Institute Research Foundation, Lowell, Massachusetts.

GENERAL INFORMATION

History

Lowell Technological Institute was incorporated in 1895 and formally opened for the teaching of textile manufacturing subjects on January 30, 1897. It was then known as the Lowell Textile School and awarded only certificates and diplomas. Growth of the school in size, prestige, and scope of curricula was rapid, and in 1913 it was granted the right to give regular four-year degrees in textile engineering and textile chemistry.

In 1928 the name was changed to the Lowell Textile Institute to indicate more fully its collegiate status. Its continued growth resulted in further diversification of its areas of specialization and within the past decade, degree programs have been added in the fields of leather engineering, paper engineering, electronic engineering, plastics engineering, general engineering, chemistry, engineering physics, and nuclear science and engineering.

In view of the present greatly expanded scope of its engineering program, its name was once more changed in 1953 to the Lowell Technological Institute. The Institute grants Bachelor of Science, Master of Science, and Doctor of Philosophy degrees.

Since 1918, when the property of the school was transferred to the Commonwealth of Massachusetts, it has been under the control and management of a Board of Trustees appointed by the Governor.

Accreditation

The Institute is a full member in the Senior College Division of the New England Association of Colleges and Secondary Schools. The United States Department of Education and the Armed Forces consider such membership equivalent to regional accreditation. The Engineers' Council for Professional Development extends full accreditation to the curricula in textile engineering.

Graduates of this Institute have been accepted for graduate study at nearly all leading universities. The Institute's prestige in its early field of specialization, textiles, has attracted students annually to L.T.I. from approximately 35 other countries.

Coeducation

The Institute accepts both men and women for entrance provided they are properly qualified graduates of an accredited secondary school. While the great majority of its students are men, the Institute has attracted for some years a small but significant group of young women who recognize the increasing opportunities open to technically trained women in industry.

Location

Lowell Technological Institute is located 25 miles north of Boston in Lowell, Mass., a city of 100,000, long famous as a textile center and more recently as a city of increasingly diversified industries. The campus is composed of ten main buildings located on a 15-acre site along the west bank of the Merrimack River and overlooking the rapids of Pawtucket Falls. The campus site was donated by Frederick Fanning Ayer, Esquire, and the Proprietors of the Locks and Canals on the Merrimack River. Another classroom and laboratory building is currently under construction.

Buildings

Southwick Hall. This was the first building erected on the present campus and was dedicated in 1903 as the gift of the Commonwealth of Massachusetts and Frederick Fanning Ayer. It is a memorial to Royal Southwick, an ancestor of Mr. Ayer and a leading textile manufacturer and public figure of his day. It contains the gymnasium, student mail room, administrative offices of the Engineering Division and the AFROTC detachment, and the national headquarters of the American Association of Textile Chemists and Colorists.

Kitson Hall. Completed in 1903, Kitson Hall was erected by Charlotte P. Kitson and Emma K. Stott as a memorial to their father, Richard Kitson, founder of the Kitson Machine Company of Lowell. It contains classrooms and laboratories.

Falmouth Street Building. Erected in 1903 as a one-story building, it was enlarged to its present capacity for classroom and laboratory facilities in 1907 by the Commonwealth of Massachusetts.

Louis Pasteur Hall. Originally constructed as a one-story building, it was enlarged to four stories in 1937 by the Commonwealth of Massachusetts and houses laboratories and classrooms as well as the national research laboratories of the American Association of Textile Chemists and Colorists.

Olney Hall. Completed in 1952 by the Commonwealth of Massachusetts, this modern building houses complete leather and paper manufacturing facilities, advanced textile testing and electronic laboratories, and many modern lecture rooms.

Alumni Memorial Library. Erected in 1951 by the Alumni Association through contributions from alumni and friends of the Institute, the modern library is dedicated to the men and women of the Institute who served this nation in World Wars I and II and the Korean conflict.

Besides a book stack capacity of 80,000 volumes, it contains student activity offices, alumni offices, reading rooms, typing facilities, a microfilm room, and faculty studies. It houses one of the most

complete collections of textile books in the world and numerous special collections in the fields of paper, leather, chemistry, electronics, and plastics. It also serves as a depository for U. S. Government publications and is available to industrial concerns through its Industrial Corporate Membership program.

Cumnock Hall. Completed in 1954, this auditorium-administration building provides a 1000-seat auditorium for academic convocations and social activities. It also contains the offices of the President and Assistant to the President, the Dean of Faculty and the Dean of Students, Graduate School, Admissions, Special Services, Placement, the Bursar, the Registrar, and the L.T.I. Research Foundation.

Smith Hall. Erected in 1948 by the L.T.I. Building Association, Smith Hall has living accommodations for 112 students. The basement contains the college cafeteria and a medical dispensary. It was dedicated in honor of James T. Smith, pioneer educator in the textile field and the individual primarily responsible for the organization of the Lowell Textile School in 1895.

Eames Hall. The second men's residence hall was completed in 1949 by the L.T.I. Building Association and contains living quarters for 112 students, a student lounge and recreation center, and a snack bar. It was dedicated in honor of Charles H. Eames, President of the Institute from 1905 to 1945.

Equipment

The total value of the scientific and industrial equipment used in the instructional and research programs of the Institute is approximately $12,500,000. This equipment ranges from the most delicate scientific instruments, such as the electron microscope, to full-sized industrial machines.

Textile manufacturing equipment can process all fibers, natural and man-made, by all common systems from raw stock to finished fabrics.

The textile testing laboratories are among the most completely equipped in the world and have the use of the extensive optical and electronics facilities used in advanced research work.

In the completely equipped paper and leather laboratories both leather and paper of nearly all grades and types can be fully processed from raw materials, finished, and tested by the most modern methods.

The wide variety of electronic and plastics equipment already available is in the process of being greatly augmented and consolidated in the newly expanded electronics and plastics laboratories.

Complete mechanical, electrical and chemical laboratories of the usual types round out the unusual variety of equipment available for instruction and research.

ADMISSION OF UNDERGRADUATES

New students at the Lowell Technological Institute are selected from those applicants who, during their preparatory education, have shown promise in scholastic ability and strength of character. In addition to scholastic rating and test results, a high value is placed on evidence of leadership and contributions to school and community life.

Application Procedure

Formal application for admission should be made as early as possible after the first marking period in the candidate's senior year of secondary school. Students from other countries are strongly advised to begin admission procedures not less than twelve months in advance of the expected date of enrollment.

Preliminary correspondence before the senior year is welcome and frequently helpful to the student in planning his secondary-school program to fit the needs of his freshman year at the Institute.

Requests for application blanks and all correspondence relating to matriculation at the Institute should be addressed to the Director of Admissions.

Steps to be taken for admission follow:

1. The first two pages of the admission application form should be completed by the candidate.

2. Attach a certified check or money order in payment of the application fee of $10. (See "Student Expenses" for explanation.)

3. The whole application form should then be submitted to the office of the candidate's secondary-school principal, with the request that his office fill out pages 3 and 4 and mail the completed application directly to the Director of Admissions.

It is recommended that this procedure be accomplished as soon as possible in the candidate's senior year in secondary school so that he may be considered for admission to classes beginning the next September.

4. All candidates for admission must make direct application to the College Entrance Examination Board, P. O. Box 592, Princeton, New Jersey, with a request to take the Scholastic Aptitude Test.

Applicants for admission in the upper 20% of their high-school class may be admitted by the Chairman of the Committee on Admissions prior to the candidates' completion of the entrance examinations.

Late applicants will be given particular direction regarding entrance examinations by the Director of Admissions.

If the candidate for admission wishes to be an applicant for scholarship aid, a formal application for a scholarship must be made with the Institute.

5. Each applicant must submit to a complete health examination by his family physician. A certificate of good health, indicating the date of this examination, must then be sent in duplicate by the physician to the Director of Admissions. The Institute has prepared a special form for the convenience of the physician; two copies of this Certificate of Health will be supplied.

Each applicant must also file a Certificate of Residence that must be completed both by the applicant and by the city or town clerk of his place of residence.

6. All admission records once submitted become the property of the Institute and will not be returned.

7. Upon receipt of his letter of admission, the applicant must submit a prepayment of tuition (one-half of the first semester's tuition) within thirty days. This fee is nonrefundable.

8. A personal interview with the Director of Admissions is strongly recommended. The Office of Admissions at the Institute is open for this purpose Monday through Friday from 8:30 a.m. to 4:00 p.m. during the school year. *It is urged that appointments for interviews be made in advance.*

Requirements for Admission

The Director of Admissions, in conjunction with the Committee on Admissions, reviews all applications to determine the eligibility of each candidate for matriculation. The final decision as to the eligibility of an applicant shall be left to the discretion of the Institute.

The conditions under which an applicant may be accepted are as follows:

1. A candidate for admission must be a graduate of a secondary school approved by the New England Entrance Certificate Board, the Regents of the State of New York, or a board of equal standing.

2. (a) Because of the specialized nature of the various curricula at Lowell Technological Institute, it has been deemed advisable that all entering students shall have completed the following units of secondary-school study:

algebra (quadratics and beyond)	2 units
plane geometry	1 unit
trigonometry	½ unit
English	4 units
American history	1 unit
chemistry (including laboratory)	1 unit
or	
physics (including laboratory)	1 unit

Preference will be given to applicants offering both chemistry and physics. In addition to the above-listed prerequisites, each applicant may offer credit in elective subjects, such as languages, other than English; history, other than American; mechanical drawing; solid geometry; advanced algebra; calculus; scientific subjects and social studies.

(b) The combined prerequisites and electives should total at least 15½ Carnegie units. Each such unit of preparatory credit is the equivalent of one secondary-school subject satisfactorily pursued during one academic year of at least thirty-six weeks of four forty-minute meetings each week, or the equivalent.

(c) In evaluating the credits offered by an applicant for admission, the Institute will be guided primarily by the quality of his scholastic record and by his apparent promise on grounds of intellect and character. Therefore, an applicant whose preparation has not followed the normal pattern with respect to the accumulation of unit credits should not hesitate to apply for entrance, provided that the quality of his scholarship gives evidence of ability to do college work and provided that he is recommended by his school.

Admission with Advanced Standing

Transfer students must submit transcripts of their college record, a copy of their college catalogue and letters of honorable dismissal well in advance of their planned transfer date.

Transfer credit will be given for courses satisfactorily completed with a grade of C or better that are the equivalent in quality and scope of those given at the Institute. Final decision on transfer credit rests with the Divisional Chairman and the Dean of Students.

Additional advanced credit will not be given a student, once he has matriculated, for courses completed prior to his admission.

Special Students

Qualified applicants may be accepted for specialized work not leading to a degree. The plan of study should have a clearly defined objective and should not deviate markedly from the regularly formulated subject matter and laboratory courses at the Institute. Admission as a special student is contingent upon approval by the Director of Admissions and the Divisional Chairmen concerned in the proposed program.

Students from Other Countries

Each year Lowell Technological Institute accepts for admission foreign applicants up to 5% of the total number of students in any

given class (freshman, sophomore, etc.). There are no special procedures to be observed by foreign candidates, although it is urged that they endeavor to have the transcript of their secondary-school and/or college records, as well as all other admission materials, submitted, in English, *not less than twelve months in advance of the expected date of enrollment.* All applicants should have a considerable facility in speaking and writing English, and have financial resources sufficient at least for their first year of study. Foreign students will be expected to complete the same schedule of courses as is assigned to all other students.

In all respects, the admission procedures for foreign students are identical with those required of U. S. citizens.

To facilitate their adjustment to the life of the campus, all male students from other countries are required to live in the residence halls of the Institute and are assigned room space shared jointly with American students. Students attending for the first time should note that towels, sheets, pillowcases, and blankets must be supplied by occupants of rooms or by a laundry service that is provided to all resident students on a voluntary basis. Students are also reminded that bedding, as well as clothing, should be suitable for a climate in which temperatures normally fall well below the freezing point during the winter months.

STUDENT HOUSING AND SERVICES

Residence Halls

All male students are required to live in the residence halls unless excused in writing by the Dean of Students. These excuses are subject to review at the beginning of each semester and may be cancelled should conditions warrant.

Application for permission to occupy other living quarters may be made on special blanks available at the Dean of Students' Office. An application must be filed annually by each student. Deadlines for filing applications are: (a) for all new students (incoming freshmen, transfer students, special students, or graduate students) —on or before September 1 of each year; (b) for all regularly enrolled students—on or before June 1 of each year.

In granting special permission to live outside the residence halls, the Dean of Students will give full consideration to the following:

a. Distance from Institute to place of legal residence.

b. Financial hardships involved in living in residence hall.

c. Year of the student (freshman, sophomore, junior, senior, graduate).

d. Membership in fraternities that maintain a fraternity house.

Rooms are furnished by the Institute but are cared for by the students occupying them. Sheets, pillowcases, blankets, towels, and other personal linens must be supplied by each student, or he may subscribe to the laundry service that is provided to all resident students on a voluntary basis. Each occupant is held responsible for any damage done to furniture and equipment.

Assignments of rooms in the residence halls are made through the Office of the Dean of Students for the full academic year. Change of room is not permitted except under unusual circumstances and may be accomplished only after a formal application has been approved by the Dean of Students.

The uniform rental charge is $275 per academic year for each student. While this charge covers occupancy during periods that the Institute is regularly in session, itmay, at the option of the Institute, be extended to vacation periods.

Assignments of rooms are made as equitably as possible and in the order that applications are received. For those students who are unable to be placed in residence halls, the Dean's Office supplies a list of approved rooming houses where students may reside.

All students are cautioned to make no legal agreements or sign residence leases with persons outside the Institute. Outside residence permits are reviewed each semester and may be cancelled should conditions warrant.

Dining Hall

Dining facilities are provided on the campus in a cafeteria located on the ground floor of Smith Hall and in a snack bar located in the Students' Lounge in Eames Hall. These facilities provide additional opportunities for the students to become better acquainted as well as assure wholesome food and a balanced diet.

Guidance

The guidance program begins with the admission procedures, continues throughout the undergraduate years, and culminates in the work of the Placement Office as outlined on page 52.

Guidance in the freshman year stems mainly from the results of the diagnostic testing program, Freshman Week activities, and conferences with the faculty throughout the freshman year. During the sophomore, junior and senior years the heads of departments and the Dean of Students take over the primary responsibility for the students' personal and scholastic guidance.

The Office of the Dean of Students is open to all undergraduates from 9 a.m. to 5 p.m. daily to assist the student in attaining his academic objective, and to assure his active, enjoyable participation in the work and affairs of the Institute.

Health Service

The dispensary, in Smith Hall, is in charge of a registered nurse eight hours each school day. She is on call twenty-four hours daily, including week ends. Students receive first-aid treatment at the dispensary and are advised as to the best procedure in case of illness.

Medical services are available to the Institute twenty-four hours daily. If any student requires hospitalization, the college physician will arrange for admission to one of the three excellent, modern hospitals located in the immediate vicinity of the Institute. Medical fees and hospital charges are at the expense of the student.

Accident insurance during the academic year is compulsory and is included in the Activity and Insurance Fee. Sickness insurance is also available on a voluntary basis through the Office of the Dean of Students.

STUDENT REGULATIONS

Conduct

Students admitted to Lowell Technological Institute are assumed to be ladies and gentlemen and of sufficient maturity and poise to enable them to live in an adult environment. Such living involves full respect for the rights of others, a regard for self-discipline and good order, and a high standard of honesty and of moral conduct.

In consequence of these assumptions, the regulations are framed not to restrict the conduct of individuals or groups of students. They simply set forth the basic policies established by the Faculty in order that a large student body may live and work harmoniously together with a minimum of friction and misunderstanding. By the same token, even though the rules are neither detailed nor comprehensive, a student may be dropped from the rolls or subjected to other disciplinary action for conduct which is illegal, immoral, or inimical to the best interests of the Institute. This holds whether or not the particular offense is listed in these rules and regulations.

Attendance

Attendance is expected of all students at all classes. The supervision of student attendance is lodged in the Office of the Dean of Students, both as to the announcement of detailed instructions and the enforcement of the rules established by the Faculty. Students charged with unexcused absences, particularly absences immediately before and after holiday and vacation periods, are subject to disciplinary action.

Disciplinary Action

Disciplinary action originates in the Office of the Dean of Students. Such action may be in the form of any of the following degrees of severity: Censure, Restriction, Suspension, or Dismissal. Whenever disciplinary action is taken, a notation of such action becomes a part of the permanent record of the student.

Academic Grades

The students' grades are reported by letter as follows:

A	90-100	F	Below 60, Failure
B	80-89	I	Incomplete
C	70-79	W	Withdrawn
D	60-69	X	Dropped

The student's semester rating is a weighted value used to denote his relative standing. Values assigned are as follows: A = 4 points, B = 3 points, C = 2 points, D = 1 point and F = 0 points. These point values, when multiplied by the credit hours assigned to the subject and added together, are divided by the sum of the credit hours to give the student's semester rating. The cumulative rating for more than one semester will be obtained in the same manner as the computation for the rating of a single semester.

Scholastic Reports

Reports of scholastic standing are compiled regularly at the end of each semester and formal notification of each student's status is made at that time.

Dean's List

The Dean's List is composed of those students who have a semester rating of 3.00 or higher, with no current failures.

Probation

A student is placed on probation when his semester rating is below 1.30.* The probationary period covers the entire semester following the issuance of the semester rating which placed the student on probation.

A student on probation may not represent the Institute in any public function and may not hold class or other offices during his term of probation.

A student with a rating of less than 1.30* for two consecutive semesters shall be dropped from the Institute for at least one semester.

If a student receives a semester rating below 0.70* he shall be automatically dropped from the Institute without benefit of a probationary period.

REQUIREMENTS FOR GRADUATION

Only those students who have satisfied the following minimum requirements will be recommended for the baccalaureate:

(1) Complete successfully one of the prescribed curricula with no substitutions for major subjects therein and no unremoved failures in a major subject.

(2) Earn a cumulative rating of 1.7 or better for the entire period at the Institute.

(3) Pass 80% of the credit hours offered towards the degree with grades higher than D.

* Commencing with the Class of 1962.

Graduation Honors

Academic honors are awarded at the annual Commencement Exercises by appropriate notation on the diplomas for the baccalaureate degree, and by printing in the Commencement program the names of students who have earned such recognition. Honors are awarded according to the following standards of achievement:

a. Any student who graduates with a rating of 3.00 for the entire period of study at the Institute shall be awarded the baccalaureate degree *"With Honors."*

b. Any student who graduates with a rating of 3.30 or better for the entire period of study at the Institute shall be awarded the baccalaureate degree *"With High Honors."*

c. The highest ranking student in each graduating class who graduates with a rating of 3.7 or better, and who has completed at least six semesters of work at the Institute, shall be awarded the baccalaureate degree *"With Highest Honors."*

STUDENT AWARDS

The following awards are made annually by the Scholarship and Awards Committee:

(1) *American Association of Textile Chemists and Colorists Book Prize*

Awarded to the outstanding graduating senior in the course of Textile Chemistry. The recipient is recommended by the Chemistry Division and the academic standing of the candidate is an important factor. The award includes a junior membership for one year in the A.A.T.C.C.

(2) *American Association for Textile Technology Award*

Given annually to the member of the senior class majoring in textiles who is rated highest on the basis of scholarship, technical ability, industry, judgment, leadership, reliability, and ability to work with others.

(3) *Chemistry Department Award*

A book prize is awarded to the member of the freshman class who shows the highest achievement in Freshman Chemistry during the first semester.

(4) *National Association of Cotton Manufacturers Award*

Given to the member of the graduating class in Textile Engineering (General Manufacturing Option) or Textile Technology who has maintained the highest scholastic standing throughout the four years of his undergraduate work.

(5) *Louis A. Olney Book Prizes*

Selected reference books are awarded annually to the outstanding freshman, sophomore, and junior students in the course of

Textile Chemistry. The recipients are recommended by the Chemistry Division chiefly on the basis of academic standing in chemical subjects.

(6) *Phi Psi Award*

Given annually to an outstanding member of the graduating class on the basis of scholastic standing, leadership, initiative, personality, loyalty, and courtesy.

(7) *President's Medal*

This award is made at Commencement to the student graduating with the most distinguished academic record in his class and *"With Highest Honors."*

(8) *Textile Veterans Association Honor Award*

This Association, representing all the veterans of World War II now affiliated with the textile and allied industries, has established an annual honor award, in the form of a suitably engraved bronze medallion. It is given to an outstanding graduating senior in a textile course on the basis of scholastic standing, extracurricular activities, and over-all contribution to the Institute. (Preference is given to veterans.)

(9) *The Dean's Key*

This award, sponsored by the Student Council, is made annually to the member of the senior class who, in the eyes of a committee selected by the Dean of Students and composed of faculty and administrative personnel, has made the greatest extra-curricular contribution to the Institute during his four years of college.

(10) *Samuel P. Kaplan Memorial Fund Awards*

The New England Knitted Outerwear Manufacturers' Association has set up a fund in memory of Samuel P. Kaplan to enable two prizes to be awarded each year to outstanding students in the basic knitting course. An award of $100 will be granted to the highest-ranking student at the end of the first semester and a similar award will be made at the end of the second semester.

(11) *Barnett D. Gordon Award*

The Barnett D. Gordon Award of $250 is to be presented to the young man or young woman who achieves the highest rank in the mathematical section of the Scholastic Aptitude Tests which are required of all entering freshmen applying for admission to L.T.I.

(12) *The Circle K Book Award*

This award consists of a book which is awarded annually to the freshman with the highest cumulative average for the first semester of his first year at the Institute.

(13) *Helen U. Kiely Award*

This award, made at Commencement, acknowledges by permanent inscription on a plaque the senior student in Paper Engi-

neering selected by his classmates as having outstanding qualifications of merit. It is made by the New England Section of the Technical Association of the Pulp and Paper Industry in recognition of Helen U. Kiely's distinguished service to the industry.

STUDENT EXPENSES*

The various student expenses described in this section apply only to the regular day school of Lowell Technological Institute. The fees and expenses of the Evening Division are described in a separate bulletin. All fees are established by the Board of Trustees and are subject to change without advance notice.

Payment of tuition and fees is an integral part of the registration process which must be completed before a student may attend classes. In special cases a delay in the payment of fees may be authorized, but all fees must be paid on or before the close of the sixth week of classes of the semester involved. Requests for delay must be approved before a student's registration is complete.

Application Deposit $10

Payable by certified check or money order and filed with the Director of Admissions at the time of application.

a. If the applicant is accepted for admission and is duly enrolled as a student at the Institute, the entire amount of this deposit shall be credited toward his tuition charges on the day of registration.

b. If the applicant is not accepted for admission as a student, the entire amount of this deposit shall be refunded.

c. If the applicant is accepted for admission but does not choose to enroll as a student, no refund shall be made.

d. If the applicant is accepted for admission but is called to duty in the Armed Services of the United States, he shall, upon presentation of suitable evidence of this fact, be entitled to a refund of the entire amount of the application deposit.

e. The Institute requires the prepayment of 50% of the first semester's tuition within 30 days after the applicant has been accepted for admission. For Massachusetts residents this amounts to $50. This prepayment will be forfeited if the student fails to register at the Institute. In rare cases,

* The matter of student expenses is currently under consideration by the Board of Trustees and is subject to revision.

such as sickness which would prevent the applicant from coming, this rule may be waived at the discretion of the Dean of Students.

Tuition	(per year)
U. S. citizens who are residents of Massachusetts	$200
U. S. citizens who are residents of states other than Mass.	$300
All others	$550

Special students pay, in general, the full tuition fee. However, if enrolled in only a limited number of courses, a special student may make application to the President for a reduction in tuition.

Because Lowell Technological Institute is a state-supported institution, its educational program and facilities are made available at a low tuition rate to students entering from the Commonwealth. Eligibility for admission as a student entitled to the low residential tuition is determined under policies established by the Board of Trustees.

a. Every student claiming residence in Massachusetts must file with the Dean of Students a certificate signed by either the town or city clerk of the community claimed as legal residence, stating that the student's parents or guardian is a legal resident of the Commonwealth of Massachusetts.

b. The residence of a minor shall follow that of the parents, unless the minor has been emancipated. A minor student who has been emancipated shall, in addition to the requirements respecting residence, present satisfactory documentary evidence of emancipation.

c. A minor under guardianship shall be required to present satisfactory documentary evidence of the appointment of a guardian in addition to the certificate of residence of the guardian.

d. The residence of any applicant for admission, as shown on the application for admission at the time of initial application, shall determine the appropriate tuition charge to be made for the entire period or periods of the applicant's enrollment as an undergraduate, graduate, and/or special student.

e. The residence of a wife shall follow that of the husband.

f. The prescribed form of application for classification as to residence shall be executed by each student. Misrepresentation of facts to evade payment of the proper rate of tuition shall constitute sufficient cause for suspension or permanent separation from the Institute.

g. Payment of one-half of the total yearly tuition will be made during the registration for each semester.

h. The President of the Institute is authorized to adjust individual cases within the spirit of these rules.

Note: Wherever mentioned above, the word *residence* is considered to mean *legal domicile.*

ROTC Deposit $25

This deposit covers loss of, or damage to, uniform or equipment used for ROTC instruction. It is required of all students enrolled in ROTC. The entire amount, less charges, will be refunded upon the completion of the ROTC requirements. If, at any time, the charges against a student exceed the amount on deposit, the student will be required to pay such charges and to make an additional deposit of $25.

Activity and Insurance $40

Each student will pay $40 the first semester for the entire academic year as a student activity and insurance fee. The payment of this fee entitles the student to free admission to all athletic events, a mailbox in the campus post office, a subscription to the student newspaper, and a copy of the yearbook. A portion of this fee helps to support the general student activities under the jurisdiction of the Student Council. It pays for the compulsory accident insurance policy which covers each student against accidents during the academic year and also contains a compulsory bonding fee which protects the Institute against unpaid student charges.

Residence Halls $275

All students, except those who live in Lowell or the surrounding community, may be required to live in one of the residence halls (see page 25 for details). The double rooms rent for $275 per student per year. One-half of the rent ($137.50) is payable at the start of each semester.

Laboratory and Materials Fee

To cover the cost of materials and normal breakage in all laboratories, each student will be charged as follows:

All freshmen $12/semester

Upperclassmen enrolled in:

(a) Textile Technology, Textile Engineering, General Engineering, Engineering Physics, Nuclear Science and Engineering, or Electronic Engineering . $12/semester

(b) Paper, Leather, or Plastics Engineering $17/semester

(c) Textile Chemistry and Chemistry . $22/semester

The above charges are not refundable. Excess breakage will be billed direct to the student. These fees are payable each semester regardless of the number of laboratories taken and represent an average flat charge per semester for the regular four-year program in each of the above courses.

The above fee must be paid before a student can be admitted to laboratory work.

Commencement Fee (Seniors only) $15

This covers Commencement expenses such as degree and case, rental of cap and gown, invitations, printing, and such other expenses as shall be approved or directed by the President.

Late Registration Fee $5

Any student who does not complete his registration (including the payment of all fees) by the close of the registration period may be required to pay an additional fee of $5.

Official Transcript Fee $1/copy

Each student will be allowed free of charge a total of three transcripts of his scholastic record. A charge of $1 per copy will be made for each *additional* transcript.

Auditing Fee . . . . $5/credit hour

All students regularly enrolled and paying the full tuition charge in any semester may audit courses in that semester without charge provided proper approval is obtained.

Students not regularly enrolled or not paying the full tuition charge for the semester must pay $5 per credit hour to audit a course and must obtain proper approval.

Books and Materials—Students must provide their own books, stationery, tools, etc., and pay for any breakage or damage that they cause to machines, laboratory equipment, and other property of Lowell Technological Institute.

All raw stock and yarn furnished to the students, and all the productions of the Institute, remain or become its property, except by special arrangement, but each student is allowed to retain specimens of yarn or fabrics that he has produced, if mounted and tabulated in accordance with the requirements of the department. It is understood that the departments may retain such specimens of students' work as they may determine.

No books, instruments, or other property of the Institute loaned to the students are to be removed from the premises except by special permission.

Refund Schedule—Applications for refunds, filed with the Bursar on withdrawal, will be made in accordance with the following table:

No. of Weeks		*Refund*
At least	*But less than*	*Rate*
0	2	80%
2	3	60%
3	4	40%
4	5	20%
5 and over		None

SUMMARY OF EXPENSES PER YEAR

Tuition	
U. S. citizens who are residents of Massachusetts	$200
U. S. citizens who are residents of states other than Mass.	$300
All others	$550
Dormitory rate	275
Laboratory and Materials Fee	
(a) All freshmen	24
(b) Upperclassmen enrolled in:	
Electronic Engineering, Engineering Physics, General Engineering, Nuclear Science and Engineering, Textile Engineering, or Textile Technology	24
Leather, Paper, or Plastics Engineering	34
Chemistry and Textile Chemistry	44
Student Activity and Insurance Fee	40
ROTC Deposit	25
Books, supplies and related miscellaneous expenses	100

STUDENT ACTIVITIES

Lowell Technological Institute believes that sound educational practice seeks to develop the whole personality of the student. Accordingly, Faculty and Administration encourage extra-curricular activities and support the development of a varied and well-rounded program of activities to supplement the purely academic phase of undergraduate life. This program provides opportunity for participation in formal and informal sports, in class and campus self-government, and in the many clubs and special interest activities which appeal to the varied interests of the student body.

Student Council

The Student Council is the chief body for the conduct of self-government in student affairs. It is composed of four officers elected at large by the student body, the president of each undergraduate class, and one representative from each of the classes.

By virtue of its function as chief governing body for student affairs, it exercises administrative control over all campus organizations formed under its supervision; represents the student body in matters requiring conference with the Administration and Faculty; investigates grievances submitted by students or student groups; sponsors all-campus dances, banquets, and other social affairs; and supervises the expenditure of the unallocated portion of the student activity fee. It functions in accordance with the specific prescriptions of its constitution and by-laws.

Athletics

The Athletic Association promotes an extensive varsity and intramural sports program. All students are members of the Athletic Association and receive free admission to all intercollegiate contests played at home.

Soccer, basketball and baseball are varsity sports at the Institute. Competition is chiefly with teams in the northeast portion of the country. Golf and tennis teams also compete regularly with other colleges in the area.

Intramural sports are sponsored by the Director of Intramural Athletics with an interesting year-long program of both league and informal competition between the classes, residence halls, and fraternities.

Band

The AFROTC Band is composed primarily of cadets who are musicians or who desire to learn to play a band instrument. In addition to providing the music for the AFROTC ceremonies, the

band adds considerably to the color and life of the campus by participating in various Institute and civic programs.

Circle K

The Circle K Club is the student chapter of the Kiwanis at the Institute. In addition to performing many services in the public interest, it assists the administration of the Institute in the freshman orientation program each year.

Duplicate Bridge Club

The Duplicate Bridge Club is open to all students and faculty members at the Institute. The club has approximately ten playing sessions per year to determine the championship team. Student members also participate in the annual national Intercollegiate Duplicate Bridge Tournament.

Fraternities

The Interfraternity Council fosters the common interests of the four fraternity chapters at the Institute. This organization sponsors joint social and athletic contests among the fraternities.

The four fraternities have their own houses for fraternity socials and meetings, providing centers for the social life off the campus. The fraternities are: Delta Kappa Phi, Omicron Pi, Phi Psi, and Pi Lambda Phi.

General Vandenberg Air Society

The purpose of the General Vandenberg Air Society is to unite selected advanced AFROTC cadets by a fraternal bond in order to further the mission and traditions of the Air Force. The Society is affiliated with the Air Force Association which further extends the fraternal bond to include air-minded individuals. A squadron of the General Vandenberg Air Society has been established at this Institute and is a chapter of the National Society. The Society is responsible for a cadet sports program and a variety of social affairs during the academic year. The Military Week End, the Society's social highlight, features a colorful drill ceremony and has as its climax the formal Military Ball at which announcement of the cadet officers is made.

International Students Circle

This club lists all foreign students at the Institute as its members. It serves to bring into close contact all these students who may have some difficulty in becoming adjusted to a new language or way of living. These students are in demand by local civic groups to serve as speakers on many programs.

The Nucleus

The club was initiated to serve as a focal point for students to meet and present ideas and reports regarding actual activities in industry. The club has a membership limit of fifteen members who are the leaders of all the major activities on the campus. A high scholastic rating is also a prime requisite for active participation.

"Pickout"

The "Pickout" is the annual yearbook of the campus. Those who serve on the staff secure a valuable training in the editorial, art, and business problems involved in the production of a top-quality photo-literary history of the academic year.

Professional Societies

The following societies conduct monthly meetings at which students and outstanding speakers present technical papers and lectures. Frequent field trips to industrial plants are also made by the members. These societies include:

(1) American Association of Textile Chemists and Colorists, Student Chapter
(2) American Society of Tool Engineers, Student Chapter
(3) American Society of Mechanical Engineers, Student Chapter
(4) General Engineering Society
(5) Institute of Radio Engineers, Student Chapter
(6) Leather Engineering Society
(7) Paper Engineering Society
(8) Plastics Engineering Society
(9) Textile Society
(10) Physics and Mathematics Society

Radio Station

The Radio Station (WLTI) is an all-student enterprise built and maintained by members of the Lowell Technological Institute Broadcasting Society. Programs are transmitted by a carrier current to the buildings of the campus from the station studio.

The radio station sells air time to local merchants and thus is a self-supporting organization. It provides a fine opportunity for students to learn business practices as well as broadcasting and radio techniques.

Religious Groups

Hillel. The Hillel Counsellorship was established to provide social, cultural and religious programs for the Jewish students at the Institute. Discussion groups are held weekly and brunches or

dances monthly. Speakers are invited to talk on subjects of interest to the whole student body. Hillel groups, located at most of the larger colleges and universities, are sponsored by the national B'nai B'rith organization.

Iona Student Fellowship. A group composed of students and faculty members of various races and creeds who, by uniting in a common fellowship, attempt to understand the will of God through worship, study and action, and thus realize it both in personal living and in working toward a better society.

Newman Club. The Newman Club is an organization sponsored by the Catholic students at the Institute. It conducts programs of a social and religious nature.

Rifle Team

The AFROTC Rifle Team is open to all AFROTC cadets. Competent staff members train the group, with the aid of National Rifle Association members, for intercollegiate competition matches. The major match of the year is the William Randolph Hearst Trophy Match.

Scholastic Honor Society

Membership in Tau Epsilon Sigma is open to members of the junior and senior classes who are elected on the basis of outstanding scholastic achievement and character.

Sorority

The sorority, Phi Sigma Rho, provides a center for the social life and association of the young women enrolled in the various programs of the Institute.

T.O.C.

The Tech Orientation Committee has as its special function the introduction of the new student to college life. During Orientation Week, the first week of school for the freshmen, a series of activities is planned by T.O.C. to enable freshman class members to meet each other and to realize their responsibilities to their college.

Tech Players

All the theatrical activities of the Institute are centered around the Tech Players. For years the annual production of this group has been a high point in the social calendar.

"The Text"

"The Text" is the campus newspaper. Prepared and edited by the students, this bi-weekly publication offers excellent journalistic and business experience to those who work on its staff.

Varsity Club

This club is composed of students who have earned letters in any of the intercollegiate sports, baseball, basketball, golf, soccer, and tennis. Its purpose is to help athletes academically and to foster a lasting friendship among the men participating in athletics.

FINANCIAL AID TO STUDENTS

SCHOLARSHIPS

A large number of scholarships are available to students and prospective students at Lowell Technological Institute through funds contributed by various trusts, organizations, civic bodies and industrial firms. Many of the scholarships are renewable yearly for the balance of the student's undergraduate program, provided a satisfactory scholastic average is maintained; others are only for a specified period of time.

All entering freshmen who are candidates for scholarships should make direct application to the Director of Admissions, Lowell Technological Institute, Lowell, Massachusetts, before April 1, and should have completed the Scholastic Aptitude test of the College Entrance Examination Board by that date. To arrange for this test, candidates must also make direct application to the College Entrance Examination Board, P. O. Box 592, Princeton, New Jersey, with a request to take the Scholastic Aptitude test.

Unless otherwise specified, all scholarships will be granted by vote of the Scholarship and Awards Committee of the Institute. Any student holding a scholarship must remain in good standing in college and progress normally from year to year. While honor grades are not required, scholarship holders are expected to do scholarship-level college work. Grades which prevent normal progress or conduct which results in probation, suspension, or dismissal terminates the scholarship.

Available for Freshmen and Upperclassmen

1. Albany Felt Company Scholarship

One annual grant to Lowell Technological Institute in the amount of $500 to an entering freshman is made by the Albany Felt Company. Recipients of these scholarships will be offered the opportunity for summer employment at the Albany Felt Company while in college.

2. Alumni Association Scholarships—Lowell Technological Institute

Scholarship funds under the care of the Alumni Association make available several scholarships a year which cover tuition and miscellaneous fees. These scholarships are renewable if a satisfactory scholastic standing is maintained.

3. Berkshire Hathaway, Inc. Scholarships

A number of scholarships covering tuition and living expenses for four years are offered in textile engineering and technology

by Berkshire Hathaway, Inc., Providence, Rhode Island. Eligible applicants are:

a. Male employees of Berkshire Hathaway, Inc. who have had adequate secondary-school training.

b. High-school graduates who are sons of present employees.

Interested students should contact Berkshire Hathaway, Inc., 704 Hospital Trust Building, Providence 1, Rhode Island.

4. Russell L. Brown Scholarship—donated by Davis and Furber Machine Company

This scholarship is open to a student acceptable to Lowell Technological Institute who plans to enroll in the curriculum of textile engineering or textile technology. Preference is given to employees and sons or grandsons of employees of Davis and Furber Machine Company. The selection is based on general scholarship, initiative, and need. The stipend is $300. The appointments are for one year only but are renewable.

5. Foster Grant Scholarship

A $500 scholarship to defray tuition costs of an outstanding sophomore from Massachusetts in the Plastics Engineering course has been established by Foster Grant Co., Inc. of Leominster.

6. Joseph Kaplan Scholarships

Two $250 scholarships have been established by a fund set up by Joseph Kaplan to be awarded annually to the winners of Technorama, a science fair for Merrimack Valley high schools held each year at the Institute.

7. A. C. Lawrence Leather Company Scholarship

The A. C. Lawrence Leather Company in Peabody, Massachusetts, makes available a $500 scholarship on a one-year basis to a student in leather engineering at Lowell Technological Institute. Preference is given to an employee or member of an employee's family, or to a resident in a town in which the Company operates. If no eligible applicants are available, the award will be open to any member of the Leather Engineering Department on the basis of merit.

8. Leather Engineering Department Scholarships

The Leather Engineering Department has funds for several scholarships and awards under its jurisdiction which it periodically releases for scholastic aid purposes through the Institute Scholarship Committee. These funds have been made available by interested industrial firms and trade organizations. These scholarships are available to deserving students enrolled in the Leather Engineering course who need financial assistance for scholastic purposes.

9. City of Lowell Scholarships

The City of Lowell has appropriated funds to provide a total of five scholarships every two-year period. These scholarships are awarded on the basis of competitive examinations to residents of the City of Lowell, Massachusetts, who are enrolled in the freshman class at the Institute. The amount of the scholarship is $200, which is full tuition at the Institute, and it is renewable provided satisfactory scholastic grades are maintained.

10. Commonwealth of Massachusetts Scholarships

Ten scholarships of $250 each year are available for young men and women who are residents of the Commonwealth of Massachusetts and are enrolled in the freshman class at the Institute. Awards are made on the basis of competitive examinations and the scholarships are renewable provided satisfactory grades are maintained.

11. The McLaurin-Jones Scholarship

This scholarship is awarded annually to a member of the Framingham, Needham, Tantasqua Regional, and Ware, Mass., Netcong, N. J., or Homer, La., high school graduating class, or to an employee or son of an employee of the Ludlow Papers Company (formerly the McLaurin-Jones Company) for work in the Paper Engineering Department. The scholarship for $500 is renewable from year to year for four years if a satisfactory scholastic record is maintained.

12. Mohawk Carpet Mills Textile Scholarship

A $2,000 scholarship has been made available to high-school graduates or employees of the Mohawk Carpet Mills who are residents of New York State. All applicants must have applied for enrollment in one of the various textile courses at the Institute in order to be eligible. Application must be made to the Mohawk Carpet Mills, Inc., Amsterdam, New York.

13. New England Tanners Club Scholarship

This scholarship is awarded by annual vote of the New England Tanners Club and is granted to a student in Leather Engineering at Lowell Technological Institute. Preference is given to employees of the member companies of the New England Tanners Club or to their families. If no eligible applicants are available, awards will be open to others on the basis of secondary-school scholastic performance and evidence of potential leadership. The amount of the scholarship is $1,000, awarded on a one-year basis.

14. Salem Oil & Grease Company Scholarships

Normally, two scholarships of $500 each are available each year through the Salem Oil & Grease Company in Salem, Massachu-

setts, which established the awards as a memorial to the late Harold T. N. Smith, a founder of the company. These are allocated to candidates enrolled in the Department of Leather Engineering depending on scholastic ability and financial need.

15. Shapiro Fund, Inc. Awards

Two $500 scholarships are given each year through the Shapiro Scholarship Fund, Inc. of New York City. The criteria governing these scholarships are financial need and scholastic ability.

16. Sylvan I. Stroock Scholarship—S. Stroock & Co., Inc.

Awards are made on the basis of scholarship, financial need, leadership, and promise of success in textile fields. The sum available for scholarship purposes is $500 per year, offered annually at the discretion of the Scholarship Committee.

17. H. Webster Thomas Memorial Scholarship—donated by the Rohm and Haas Corporation of Philadelphia, Pennsylvania

This scholarship is awarded for a four-year period to a student in Leather Engineering at Lowell Technological Institute. The amount of the scholarship is $500 per year.

18. United Elastic Corporation Scholarships

Scholarships in the amount of $250 are available to students taking one of the various textile courses through the United Elastic Corporation, Easthampton, Massachusetts.

These scholarships have been established primarily for employees of the United Elastic Corporation, or members of their families. Other residents of the communities where plants are located, however, may enter applications for consideration. Preference is given to native New Englanders and to those who agree to work summers in approved mills.

Qualifications for scholarships include good character and standing in the community, aptitude for technical training, and ability to pass entrance requirements of Lowell Technological Institute. With the approval of the United Elastic Corporation and the Lowell Technological Institute, scholarships may be awarded to deserving upperclassmen.

Each scholarship is for a one-year period and further extension if the performance of the student during the year is satisfactory. The United Elastic Corporation will, so far as possible, furnish suitable employment to the student during the summer vacation period and following graduation.

All applications should be made through the plant nearest the residence of the applicant. Plants are located at Easthampton, Lowell, and Littleton, Massachusetts; West Haven, Connecticut; and Stuart, Virginia.

19. Jacob Ziskind Memorial Fund for Freshmen

This scholarship was established by the employees of the Merrimack Manufacturing Company in memory of Jacob Ziskind, and is applicable to freshmen only.

Qualifications for the scholarship include good character, scholastic record, initiative and ability to pass the entrance requirements at Lowell Technological Institute.

Available for Upperclassmen Only

1. Allied Chemical Corporation Scholarship

This scholarship is to be awarded by the Scholarship and Awards Committee to a worthy upperclassman majoring in Textile Chemistry or Textile Engineering. This scholarship grant is for $500 plus tuition and is given by the Allied Chemical Corporation.

2. American Textile Machinery Association Scholarship

The Institute Board of Trustees has established an American Textile Machinery Association scholarship of $150, to be awarded to a qualified student majoring in textiles.

3. Arthur Besse Memorial Scholarship

The scholarship is awarded by the Arthur Besse Memorial Trust to a student majoring in textiles and planning to continue in that industry after graduation. Awards are based on need, scholarship, and qualities of character and leadership. The amount of the scholarship is $500 a year and is renewable if a satisfactory scholastic record is maintained.

4. Boston Paper Trade Association Scholarships

Two scholarships are open to any sophomores, juniors, or seniors enrolled in the Paper Engineering Department who are residents of New England. They are awarded on the basis of scholarship and general character. The amount of each scholarship is $150. It is anticipated that the scholarships will be made renewable each year by the Association.

5. Burlington Industries Foundation Scholarship

The Burlington Industries Foundation scholarship is valued at $1,000, payable $500 a year for the junior and senior years of the student selected by the Institute on the basis of his leadership, scholarship and financial need.

6. Chemstrand Corporation Scholarship

The amount of $500 has been made available by the Chemstrand Corporation for a superior, deserving student enrolled in the Textile Engineering course.

7. Ciba Company, Inc. Scholarship

This scholarship, donated by the Ciba Company, Inc., is in the amount of $500 each for a junior and a senior in the textile

dyeing and chemistry course at the Institute. Selection is based upon scholastic prowess.

8. Owens-Corning Fiberglas Corporation Scholarships

The Textile Products Division of the Owens-Corning Fiberglas Corporation offers two scholarships for tuition and fees valued up to $750 annually to two students in the field of engineering. Awards are made by the Institute Scholarship Committee and are renewable, provided a satisfactory scholastic average is maintained. Recipients are guaranteed summer employment by the company and will be given strong consideration for full-time employment after graduation, but they are not obligated to accept employment with the company.

9. The Gehring Foundation Memorial Scholarships—in memory of Henry G. Gehring and his son, Edward H. Gehring, both of whom were engaged in the lace industry.

These scholarships are made possible as a result of the Gehring Memorial Foundation of New York. Selection of recipients made by the Scholarship Committee may be reviewed by the Gehring Foundation. The amount of the scholarship is $75 per semester and is renewable if a satisfactory scholastic record is maintained.

10. Ralph E. Hale Scholarship

This scholarship was established by the Northern New England Section of the American Association of Textile Chemists and Colorists in memory of Ralph E. Hale, 1951 Chairman-elect of the Section and a 1931 graduate of L.T.I. This scholarship is awarded annually to a student at the completion of the junior year in the course in textile chemistry. The amount of the scholarship is $250 per year.

11. Interchemical Corporation Scholarships

Four $250 scholarships have been made available by the Interchemical Corporation of Pawtucket, R. I., to students completing two years of undergraduate work at Lowell Technological Institute. They are awarded on the basis of scholastic achievement, character, and leadership potential. Preference is given to majors in textile chemistry or allied fields.

12. New England Paper Merchants Association Scholarship

This scholarship is open to any sophomore, junior or senior in the Paper Engineering Department who is a resident of New England. It is awarded on the basis of scholarship and general character. The amount is $150. It is anticipated that it will be made renewable each year by the Association.

13. Dr. Geoffrey R. Broughton Paper Engineering Scholarships

Three prizes of $100 each are awarded at the beginning of each fall semester to the top ranking students enrolled in each of the sophomore, junior and senior classes of paper engineering.

Three prizes of $100 each are awarded at the beginning of each spring semester on the same basis. These prizes were made available by a number of interested companies for students enrolled in the Paper Engineering Department.

14. Jacob Ziskind Memorial Scholarship Fund

This scholarship was established by the Trustees of the Jacob Ziskind Trust for Charitable Purposes. Scholarships are awarded annually and are renewed provided a satisfactory scholastic record is maintained. The scholarship includes tuition, books, supplies and such other expenses as are required to enroll a student in his course. Recipients are selected by the Faculty Scholarship Committee and must have demonstrated high scholarship, financial need, and qualities of good character and leadership. Students from the sophomore, junior, and senior classes are eligible. Preference shall be given to, but not restricted to, those students who have received in their freshmen year the Jacob Ziskind Memorial Fund for Freshmen.

15. United States Rubber Company Foundation Scholarship

This scholarship is awarded to a student displaying leadership, capacity for higher education, and need. Completion of at least two years of college is required, with some evidence of an interest in a career in industry. The recipient assumes a moral obligation to repay 25% to the scholarship fund.

16. Society of Plastics Engineers Scholarship

This $200 scholarship is given by the Eastern New England Section of the Society of Plastics Engineers, Inc. to be awarded to a deserving junior majoring in Plastics Engineering. The student is selected by the Institute Scholarship and Awards Committee.

LOAN FUND

A loan fund is available for the purpose of assisting upperclassmen to continue their education at Lowell Technological Institute. Students may make application for a loan through the Faculty Treasurer of the Lowell Technological Associates, Inc.

Repayments on any loan which are made while the student is still in school are interest free. Loans repaid after the student leaves school (for whatever reason) bear 4% interest beginning three months after the date on which the student officially leaves school. Repayments are not required until the student separates from Lowell Technological Institute, at which time repayments are due quarterly at a rate of $10 per quarter the first year and $20 per quarter each year thereafter until the loan is repaid. Additional payments may be made at any time so as to reduce indebtedness at a more rapid rate.

FELLOWSHIPS

Several fellowships are available to students pursuing graduate studies.

1. Teaching Fellowships

Every year the Institute has available through the Commonwealth of Massachusetts a limited number of teaching fellowships for qualified students in the Graduate School who are working toward the Master of Science degree in Textile Chemistry or Textile Engineering. Appointees normally carry a half-time study load and are required to spend 12 to 15 hours per week in the supervision of undergraduate laboratories and review sections. Annual stipend is about $1500 with reappointment for a second year contingent on satisfactory performance of duties. Application forms may be obtained from, and must be filed prior to April 30 with, the Director of Graduate School. Appointments are made June 1 for the next academic year.

2. Research Fellowships

A limited number of research fellowships also are available to qualified students through the Celanese Corporation of America, Linde Air Products Company, and National Aniline Division, and are principally in the Division of Chemistry for students working toward the Master of Science degree in Textile Chemistry. Research may involve fundamental or applied chemistry. Appointees are expected to devote full time to study and research. Stipends are from $1200 to $1500 per year. Application forms may be obtained from, and must be filed prior to April 30 with, the Director of Graduate School. Appointments are made June 1 for the next academic year.

3. Coats and Clark, Inc. Fellowship

This fellowship is available only to graduates of textile colleges. It provides for graduate work at the Massachusetts Institute of Technology and pays approximately $700 per year plus tuition. Application should be made directly to M.I.T.

THE AIR FORCE ROTC UNIT

An Air Force Reserve Officers Training Corps unit was established at the Lowell Technological Institute on July 1, 1951. Instruction began with the opening of the first semester of the academic year 1951-52.

By vote of the Board of Trustees, all able-bodied nonveteran male students enrolling in Lowell Technological Institute for the first time on or after September 13, 1951, must satisfactorily complete the basic ROTC work (freshman and sophomore years) before receiving a Bachelor of Science degree. The President of the Institute may waive this requirement and permit the substitution of an equivalent amount of work only for those individuals who are not liable to military service under existing laws and regulations (for example, not a citizen of the United States, previous military service, etc.).

Uniforms and all equipment and textbooks required for the ROTC work will be supplied by the United States Air Force. Students in the Advanced Course will receive the standard cash payment allowed by the Air Force in lieu of subsistence.

Mission

The mission of the AFROTC unit is to develop in each cadet those attributes essential to his progressive advancement to a commission as a second lieutenant in the United States Air Force Reserve and, further, to prepare him to fill positions of increasing responsibility as a commissioned officer in such duties in the Air Force as may be required by the national defense effort.

The AFROTC program takes into consideration the fact that many of the academic subjects in which Institute students are enrolled have as much direct relationship to military duties as they have to a civilian career. The courses contained in the AFROTC curriculum have been carefully selected to augment those academic subjects. The purpose of this course of instruction, then, is to enhance the otherwise high qualifications of the student with a thorough Air Force background.

Basic Course

The work covered in the first two years is considered the Basic Course. In addition to exercises in leadership and drill, this work includes classroom instruction in the air vehicle, elements and potentials of air power, military instruments of national security, and professional opportunities in the USAF. As stated above, the satisfactory completion of the Basic Course is a requirement for the Bachelor of Science degree in all courses offered at the Institute.

Cadets who satisfactorily complete the Basic Course may apply for the Advanced Course subject to approval by the Selection Board.

Advanced Course

The Advanced Course, consisting of the last two years of Air Force ROTC instruction supplemented by a summer camp, is designed to develop in the student to the highest degree possible those understandings, attitudes, skills and attributes of leadership considered essential in the development of all Air Force commissioned officers.

Air Science III, taught during the student's junior year, analyzes such problems as command staff concepts; leadership laboratory; problem-solving techniques; communications process; principles and techniques of learning and teaching; Air Force correspondence and publications; military law and courts, and boards; applied air science, including aerial navigation, weather, and functions of the Air Force Base.

Air Science IV, taught during the student's senior year, contains a review of the previous years of air science; a critique of the summer camp training; leadership and management; military aspects of world political geography; principles of management; military aviation and the art of war; career guidance; and briefing for commissioned service.

Normally, students who successfully complete the Advanced Course are commissioned as second lieutenants in the United States Air Force Reserve and subsequently receive training as pilots or aerial observers. A limited number of students who show outstanding capability in non-flying engineering skills are also awarded commissions.

Summer Camp

In addition to completing satisfactorily the subjects required in the above generalized curriculum, each cadet enrolled in the Advanced Course is required to supplement his training by attending a summer camp of approximately four weeks duration. Usually this camp is attended during the summer preceding his senior year. Transportation from the legal residence of the cadet to the camp and return, uniforms, food, lodging, and medical and dental care are provided by the Air Force and, in addition, the cadet receives the pay of a basic airman.

Field Trips

Periodically, the Department of Air Science conducts field trips to various Air Force installations for the purpose of orientation. These trips include tours of the base and familiarization flights. Efforts are made also to assist those cadets who are interested in

flying to gain as much information as possible about the operational phase of the Air Force.

Veterans

A veteran who qualifies for and completes successfully the Advanced Course of AFROTC will be commissioned a second lieutenant in the Air Force Reserve. Under present Air Force regulations, there is no requirement for an active duty tour; however, a veteran AFROTC graduate may apply for active duty as an officer. The Professor of Air Science may waive, in consideration of military service, portions of the Basic Course which cannot be completed prior to entrance into the Advanced Course.

Contributions to Student Life

In addition to the military and academic phases of its program, the Department of Air Science sponsors various extracurricular activities which are designed to produce a well-rounded cadet. Much of this activity is undertaken by the General Vandenberg Air Society.

Cadet Decorations and Awards

A number of medals are awarded to selected cadets and cadet officers at a special Parade and Review held each spring.

Thomas F. Costello Trophy—Awarded to the AS IV cadet from the Greater-Lowell area displaying an outstanding degree of leadership ability.

Alumni Medal—Awarded annually to the outstanding cadet, regardless of class, for superior Air Science, academic and extracurricular achievement.

Convair Cadet Award—Awarded for over-all contribution to the nation's air strength.

Chicago Tribune Awards—Gold Medal for the outstanding cadet in the Advanced Course; Silver Medal for the outstanding cadet in the Basic Course.

Armed Forces Communications and Electronics Association Award—Awarded to the senior cadet demonstrating outstanding qualities of military leadership, high moral character, and definite aptitude for military service who has distinguished himself academically in the field of communications and electronics.

Sons of the American Revolution ROTC Award—Awarded to the basic cadet distinguishing himself in leadership, military bearing, and academic excellence.

Trustees' Medal—Awarded to the outstanding Air Science III cadet maintaining high academic average and demonstrating the

best performance in related classroom activities. This is presented by the Board of Trustees of the Institute.

Reserve Officers Association Medal—Awarded to the AS IV cadet distinguishing himself for leadership, excellence of character, initiative, force, personality, neatness, discipline, and related traits.

Air Force Association Medal—Awarded to the outstanding AS IV cadet on the basis of four-year achievement.

Distinguished Commander Medal—Awarded to the distinguished cadet commander, regardless of class, for outstanding performance of duty.

Distinguished Squadron Commander Medal—Awarded to cadet majors for outstanding performance throughout the academic year in leadership and drill.

Distinguished Flight Leader Medal—Awarded to two AS III cadets for outstanding performance in leadership and drill.

Distinguished Non-commissioned Officers Medal—Awarded to the two most distinguished non-commissioned officers for outstanding performance in leadership and drill.

Distinguished Air Science II Cadet Medal—Awarded to the two most distinguished AS II cadets.

Distinguished Air Science I Award—Awarded to the three most distinguished first-year basic cadets.

AFROTC Marksman Medal—Awarded to three cadets for contribution to the support of the AFROTC Rifle Team and successful marksmanship achievement in national competition of the National Rifle Association.

Distinguished Bandsman Award—Awarded to three cadets for oustanding performance in the AFROTC Band.

Distinguished Military Graduate Award—Awarded to outstanding AFROTC graduates based on four years of over-all academic and military achievement. A recipient of this award may apply for a regular commission as second lieutenant in the United States Air Force.

Distinguished Military Cadet Award—Presented annually to AS III cadets who have demonstrated a high quality of leadership, moral character, academic achievement, and aptitude for military service. This award is a prerequisite for the Distinguished Military Graduate Award.

Vandenberg Cup—Awarded to the squadron that has accumulated the highest number of points for various competitions and extracurricular participation during the academic year.

PLACEMENT

Industrial Training Program

The Placement Office with the assistance of industry endeavors to place every qualified underclassman during the summer vacation periods in an industrial position similar to the student's major field of interest at the Institute. These training opportunities are available in chemistry, electronics, leather, paper and textiles, and are open to all students who have completed their sophomore year except those on scholastic or disciplinary probation.

The objectives of the undergraduate Industrial Training Program are:

(1) To help supply essential industrial experience to the undergraduate;

(2) To provide experience in human engineering only obtained in industry;

(3) To furnish an employment pool enabling industry to preview individual students;

(4) To further the liaison between the Institute and industry.

Placement Service

The Placement Office maintains active contacts with a number of industrial firms throughout the country in each of the fields of engineering presented at the Institute. A complete file of opportunities and data on various industries and companies is available to the members of the graduating class in the Placement Office.

The office arranges for the visits of representatives from industrial firms to interview students. A series of industrial seminars is conducted in which industrial speakers outline opportunities in particular industries and the various positions within the companies.

In addition to assisting in the placement of graduating students, it also assists industry in the difficult job of locating trained and experienced personnel. The office also assists alumni to establish new connections.

The Placement Office, of course, cannot give any graduate a guarantee of employment; however, during the past year this office listed several jobs for every graduate and practically all seniors were placed before Commencement. No official part-time placement program is in operation because of the heavy academic schedule.

COOPERATIVE PLAN

Massachusetts Institute of Technology
Lowell Technological Institute

A cooperative arrangement between Lowell Technological Institute and Massachusetts Institute of Technology includes the following major provisions:

(1) The mutual use of the manufacturing and research facilities for graduate and undergraduate theses;

(2) The mutual use of textile libraries of both institutions;

(3) The opportunity for students at each institute to supplement their work by taking work presented at the other institute;

(4) The formation of joint seminars and the interchange of staff members for special lectures.

SPECIAL SERVICES TO INDUSTRY AND THE COMMUNITY

In addition to the services rendered by the Evening Division, the Alumni Memorial Library, the Research Foundation, and the Summer School program, the college provides such special services to industry and to the community as the following:

Industrial seminars and conferences;

Guidance work in the high schools;

Consultive opportunities with the Faculty;

Collaboration with the International Cooperation Administration of the Government in its foreign aid program;

Special radio and television programs.

For information relative to these programs, address The Coordinator of Special Services, Lowell Technological Institute, Lowell, Massachusetts.

SUMMER SESSION

The Summer Session is designed primarily to serve three principal areas of interest: Professional Advancement Courses for industrial personnel; Undergraduate Credit Courses for college students with course deficiencies; and Precollege Refresher Courses for incoming freshmen at L.T.I.

The industry-sponsored professional advancement program comprises a series of specialized, intensive, one- to three-week courses in textile, paper, and leather technology. The six-week undergraduate credit program stresses fundamental courses in college mathematics, physics, chemistry, English, and economics.

Precollege Refresher Courses

The precollege refresher program is especially designed to articulate the high-school training of prospective L.T.I. students with the more intensive college-level studies in basic mathematics, physics, chemistry, and English. The noncredit refresher courses are offered both in a six-week and a four-week session in order to provide adequate coverage for a number of minor deficiencies in the high-school background.

For further information on the Summer Session, write to Professor Ernest P. James, Director of Summer School.

EVENING DIVISION

The Evening Division offers a wide variety of courses in engineering, chemistry, textiles, rubber, paper, leather, electronics, plastics, the social sciences, and art. These courses are designed to fit the needs of the community, particularly those people engaged in industry who wish to further their education.

The Evening Division offers four-year associate degree courses in chemistry and in electrical, electronic, industrial, and mechanical engineering, also five-year associate degree courses in paper, leather, plastics, and rubber engineering.

Two semesters of 15 weeks each are offered, starting late in September and late in January. For further information, write to the Director of the Evening Division.

Courses of Study

UNDERGRADUATE PROGRAMS

Twelve fields of study are open to undergraduates. All are four years in length and lead to the degree of Bachelor of Science. These fields are:

- Chemistry
- Electronic Engineering
- Engineering Physics
- General Engineering
- Leather Engineering
- Nuclear Science and Engineering
- Paper Engineering
- Plastics Engineering
- Textile Chemistry
- Textile Engineering—Engineering Option
- Textile Engineering—General Manufacturing Option
- Textile Technology

These curricula, outlined in the following pages, are under constant study and are subject to revision whenever changes are necessary to enable the Institute better to fulfill its mission of service to industry.

In all courses considerable work in practical industrial applications has been included in addition to the fundamental studies in the physical sciences, mathematics, and engineering. Classes in the humanities and social sciences have been woven into all curricula in a conscious effort to produce graduates not only with a thorough technical training but also with the broad cultural background which marks the educated man.

The Freshman Program

Orientation

The first week's program in the fall for entering freshmen is called Freshman Week. It is devoted to facilitating the adjustment of the new student to his physical and social surroundings. Under the sponsorship of the Office of the Dean of Students, a program of meetings, lectures, and conferences is presented in order to acquaint the entering class with the traditions, customs, rules and regulations, courses of instruction, organizations, recreational activities, and other facilities of Lowell Technological Institute.

All new students are required to attend the program of Freshman Orientation which carries no academic credit but is designed to make the freshman aware of his new responsibilities and to help him adjust to college life. It guides him in making the most efficient use of his time and talents, and it attempts to develop his ability to think and to react thoughtfully and intelligently to new ideas and viewpoints.

Freshman Course of Study

First Semester

*AS	101	Air Science	(2-1)2
CH	101	General Chemistry	(4-2)4
EN	113	Engineering Graphics	(0-3)1
GS	111	English Composition	(3-0)3
MA	107	Introduction to Mathematical Analysis	(4-0)4
PH	103	Physics	(4-1)4
		Total credit hours	18

Second Semester

*AS	102	Air Science	(2-1)2
CH	102	General Chemistry	(4-2)4
EN	114	Engineering Graphics	(0-3)1
GS	112	English Composition	(3-0)3
MA	108	Calculus and Analytic Geometry	(5-0)5
PH	104	Physics	(4-1)4
		Total credit hours	19

In addition to the preceding schedule all nonveteran men students who are physically qualified must take physical education for the whole freshman year. This subject meets one hour per week for AFROTC students and two hours per week for all others. It carries no academic credit.

* Required of all able-bodied, nonveteran male citizens (see page 48). Other students must take in its place GS 101-102, Elements of Political and Economic Geography.

The Elective System

In all curricula an opportunity is afforded the student to elect subjects in addition to those required for graduation. These electives fall into two categories: technical electives and general electives.

Technical electives give the student a chance to broaden his professional knowledge by taking subjects allied to his main interest or to further his knowledge of a particular phase by taking additional work therein.

General electives are subjects offered by the Division of General Studies. They include cultural courses in the humanities or social sciences, or management courses to help fit the graduate for positions of executive responsibility. Normally all general electives taken by a student as an undergraduate must be chosen from one of the five cores listed below. However, in particular cases and with the division chairman's permission elective work may be divided between two cores.

I. Management Core		
GS 301	Economic Development of the United States	(3-0)3
GS 302	Modern Labor Problems	(3-0)3
GS 461	Personnel Management	(3-0)3
GS 463	Business Law	(3-0)3
GS 465	Management Problems Research	(3-0)3
II. Finance Core		
GS 307	Principles of Finance and Banking	(3-0)3
GS 341	Accounting—I	(3-0)3
GS 342	Accounting—II	(3-0)3
GS 468	Investment Fundamentals	(3-0)3
Elective		(3-0)3
III. Sales Core		
GS 321	Industrial Marketing	(3-0)3
GS 322	Industrial Marketing	(3-0)3
GS 442	Export Sales Management	(3-0)3
GS 443	Industrial Advertising	(3-0)3
Elective		(3-0)3
IV. Literature Core		
GS 222	Appreciation of Literature	(3-0)3
GS 233	Comparative Literature	(3-0)3
GS 473	The Modern American Novel	(3-0)3
GS 474	Modern Drama	(3-0)3
Elective		(3-0)3
V. History and Government Core		
GS 223	The United States since 1865	(2-0)2
GS 226	World History since 1900	(3-0)3
GS 301	Economic Development of the United States	(3-0)3
GS 470	Comparative Modern Governments	(3-0)3
GS 472	American Foreign Policy, 1774 to the Present	(3-0)3

Chemistry

Those who make Chemistry their field of concentration are provided with a basic knowledge of the four major branches of chemistry, inorganic, organic, analytical, and physical, and with advanced instruction in one or more of the same areas, to prepare either for positions in the chemical industry or for further training at the graduate level.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201M	Organic Chemistry	(3-6)5
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202M	Organic Chemistry	(3-6)5
CH	206	Qualitative Analysis	(2-6)4
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	307	Atomic and Molecular Structure	(3-0)3
CH	331	Physical Chemistry	(3-3)4
GS	201	Principles of Economics I	(3-0)3
GS	261	Technical German	(3-0)3
		*General Elective	(3-0)3
		Technical Elective	3
		Total credit hours	19

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	314	Advanced Quantitative Analysis	(2-4)3
CH	332	Physical Chemistry	(3-3)4
GS	202	Principles of Economics II	(3-0)3
GS	262	Technical German	(3-0)3
		*General Elective	(3-0)3
		Technical Elective	3
		Total credit hours	19

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

CH	423 or 431 or 443	Advanced Chemistry	(3-0)3
		*Two General Electives	(6-0)6
		Technical Electives	6
		Total credit hours	15

*AS 401, Air Science (4-1)4 may be substituted for one General Elective

Second Semester

CH	424 or 432 or 444	Advanced Chemistry	(3-0)3
		*Two General Electives	(6-0)6
		Technical Electives	6
		Total credit hours	15

*AS 402, Air Science (4-1) 4 may be substituted for one General Elective

Recommended Technical Electives for juniors and seniors: CH 333, 334, 342, 352, 403-404, 446, and 481; PH 302, 352, and 544 for seniors only; CH 408-409, 423-424, 431-432, and 443-444.

Recommended General Electives: GS 222, 223, 226, 301, 302, 303, 470, 472, 473, and 475.

NOTE: For explanation of the Elective System, see page 57.

Electronic Engineering

The objective of the curriculum in Electronic Engineering is to provide the student with a sound foundation for a professional career in electronics. Toward this end he is given a thorough grounding in electronic science and engineering together with an intensive training in mathematics and physics.

In all courses in electronics and physics the techniques of experimental science and technology are emphasized by investigative work in the laboratory and lecture demonstrations in the classroom.

Studies in the humanities and social sciences form an important part of the program since these subjects broaden the student's outlook. They also serve to focus attention on the importance of nontechnical knowledge in determining the student's ultimate level of responsibility in professional life. Emphasis is placed on the development of the student's ability to speak and write effectively so that he can express his thoughts and the results of his experimental investigations with clarity.

In addition to his formal studies, the student is encouraged and expected to do independent reading in philosophy, history, and literature, as well as supplementary work in the areas of his special technical interest.

During each semester of the undergraduate program in Electronic Engineering a case study is made of some novel topic or situation occurring in industry or in the course of an engineer's professional work. This gives the student an opportunity to develop his ability to make reasoned judgments in complex situations wherein nontechnical factors frequently are of paramount importance.

Due to limitations of staff and facilities, only a limited number of students can be accepted in Electronic Engineering. Such acceptance is based upon the student's performance during the freshman year.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EL	201	Introductory Circuit Theory	(4-0)4
EL	203	Electricity and Magnetism Laboratory	(0-3)1
EL	205	Introductory Field Theory	(4-0)4
GS	223	The United States since 1865	(2-0)2
MA	205	Calculus and Analytic Geometry	(4-0)4
		Total credit hours	17

*Alternate: GS 209, 213, 233, 261, 263, or 265 (3-0)3

Second Semester

*AS	202	Air Science	(2-1)2
EL	202	Introductory Circuit Theory	(3-0)3
EL	204	Elementary Electricity and Magnetism Laboratory	(0-3)1
EL	206	Introductory Field Theory	(3-0)3
EL	210	Electronic Circuits	(3-0)3
GS	214	Communication of Ideas	(3-0)3
MA	206	Differential Equations	(3-0)3
		Total credit hours	18

*Alternate: GS 210, 222, 224, 226, 234, 262, 264, or 266 (3-0)3

JUNIOR YEAR

First Semester

EL	305	Electronics Laboratory	(0-4)2
EL	309	Physical Basis for Electronic Engineering	(3-0)3
EL	311	Engineering Mathematics	(4-0)4
EL	321	Mechanics	(3-0)3
EL	323	Electronic Circuits	(3-0)3
		*Elective from the list below	3 or 4
		Total credit hours	18 or 19

*GS 209, 213, 233, 261, 263, 265, 301, 303, 361, 371; AS 301

Second Semester

EL	306	Electronics Laboratory	(0-4)2
EL	310	Electromagnetics	(3-0)3
EL	312	Engineering Mathematics	(4-0)4
EL	322	Thermodynamics	(3-0)3
EL	324	Network Analysis	(3-0)3
		*Elective from the list below	3 or 4
		Total credit hours	18 or 19

*GS 210, 222, 224, 226, 234, 262, 264, 266, 362, 372; AS 302

SENIOR YEAR

First Semester

EL	401	Servomechanisms	(3-0)3
EL	405	Communication Electronics	(3-0)3
EL	411	Applied Electronics Laboratory	(0-4)2
		*Two Technical Electives	6
		†General Elective from the list below	(3-0)3
		Total credit hours	17

*AS 401, Air Science (4-0)4 may be substituted for one Technical Elective.

†GS 209, 213, 233, 261, 263, 265, 301, 303, 311, 361, 473

Technical Electives

EL	403	Microwave Electronics	(3-0)3
EL	407	Pulse and Digital Circuits	(3-0)3
EL	409	Electronic Projects Laboratory	(0-4)2
EL	429	Special Topics in Electronics	(3-0)3
EL	433	Solid State Physical Electronics	(3-0)3
EL	435	Instrumentation	(3-0)3
EL	437	Introduction to Scientific Research	(2-0)2

Second Semester

EL	402	Servomechanisms	(3-0)3
EL	406	Communication Electronics	(3-0)3
EL	412	Applied Electronics Laboratory	(0-4)2
		*Two Technical Electives	6
		†General Elective from the list below	(3-0)3
		Total credit hours	17

*AS 402, Air Science (4-1)4 may be substituted for one Technical Elective.

†GS 210, 222, 224, 226, 234, 262, 264, 266, 362, 372, 470, 472, 475

Technical Electives

EL	404	Microwave Electronics	(3-0)3
EL	408	Pulse and Digital Circuits	(3-0)3
EL	410	Electronic Projects Laboratory	(0-4)2
EL	430	Special Topics in Electronics	(3-0)3
EL	434	Solid State Physical Electronics	(3-0)3
EL	436	Instrumentation	(3-0)3
EL	440	Experimental Techniques	(1-1)1
GS	314	Philosophy of Science	(3-0)3

NOTE: For explanation of the Elective System, see page 57.

Engineering Physics

This program was developed to meet the demands of industry, education, and government for people with an intensive training in physics and mathematics and the ability to put their knowledge to use in helping to solve some of the problems of the current crisis in science, as researchers or teachers. It is intended to challenge the student to his greatest achievements and should not be contemplated by any who do not find themselves on the best of terms with mathematics.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
GS	261	Technical German	
or			(3-0)3
GS	265	Elementary Russian	
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
PH	211	Intermediate Mechanics	(3-0)3
PH	251	Intermediate Electricity	(3-3)4
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
GS	262	Technical German	
or			(3-0)3
GS	266	Elementary Russian	
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
PH	222	Intermediate Thermodynamics	(3-0)3
PH	254	Electronics	(3-3)4
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

MA	301	Advanced Calculus	(3-0)3
PH	311	Physical Mechanics	(3-0)3
PH	343	Atomic Physics	(3-1)3
PH	353	Electromagnetic Theory	(3-0)3
PH	355	Physical Electronics	(3-3)4
		*General Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 301, Air Science (4-1)4

Second Semester

MA	302	Advanced Calculus	(3-0)3
PH	324	Statistical Mechanics	(3-0)3
PH	358	Electrical Measurements	(2-3)3
PH	362	Intermediate Nuclear Physics	(3-0)3
		*Two General Electives	(6-0)6
		Total credit hours	18

*AS 302, Air Science (4-1)4 may be substituted for one General Elective

SENIOR YEAR

First Semester

MA	403	Modern Mathematical Methods	(3-0)3
PH	411	Quantum Mechanics	(3-0)3
PH	461	Nuclear Physics	(3-0)3
PH	471	Solid State Physics	(3-0)3
PH	493	Advanced Laboratory	(0-4)1
		*Two General Electives	(6-0)6
		Total credit hours	19

*AS 401, Air Science (4-1)4, may be substituted for one General Elective

Second Semester

MA	404	Modern Mathematical Methods	(3-0)3
PH	412	Quantum Mechanics	(3-0)3
PH	462	Nuclear Physics	(3-0)3
PH	472	Solid State Physics	(3-0)3
PH	494	Advanced Laboratory	(0-4)1
		One Technical Elective	3
		*One General Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 402, Air Science (4-1)4

NOTE: For explanation of the Elective System, see page 57.

General Engineering

The General Engineering curriculum is designed to give the student a fundamental preparation for a wide variety of positions in industry, because of industry's growing need for men who are versatile in their engineering capabilities, soundly trained in the basic principles which underlie all engineering, and therefore adaptable to assignment to numerous positions in modern industrial organizations. Notably, the graduates of this curriculum are equipped to deal with electromechanical systems, which are increasingly forming the core of present-day industry.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	203	Mechanism	(2-3)3
EN	221	Applied Mechanics I	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	226	Applied Mechanics II	(3-0)3
EN	232	Engineering Materials	(3-2)4
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	211	Machine Tool Laboratory	(1-2)1
EN	303	Electrical Circuits	(3-2)3
EN	305	Thermodynamics	(3-0)3
EN	317	Applied Mechanics III	(3-0)3
		General Elective	(3-0)3
		*Technical Electives	7
		Total credit hours	20

*May include AS 301, Air Science (4-1)4

Technical Electives

CH	331	Physical Chemistry	(3-3)4
EN	307	Surveying and Structures	(3-3)4
EN	309	Metals Processing	(2-2)3
EN	313	Advanced Mechanism	(2-2)3
MA	301	Advanced Calculus	(3-0)3

Second Semester

EN	316	Applied Thermodynamics	(3-3)4
EN	344	Electrical Machinery	(3-2)4
PH	352	Electronic Circuits	(3-2)4
		General Elective	(3-0)3
		*Technical Elective	3 or 4
		Total credit hours	18 or 19

*Alternate: AS 302, Air Science (4-1)4

Technical Electives

CH	332	Physical Chemistry	(3-3)4
CH	352	Chemical Engineering	(3-0)3
EN	308	Structures	(3-0)3
EN	320	Mechanical Vibrations	(3-0)3
EN	336	Physical Metallurgy	(3-0)3
MA	302	Advanced Calculus	(3-0)3

SENIOR YEAR

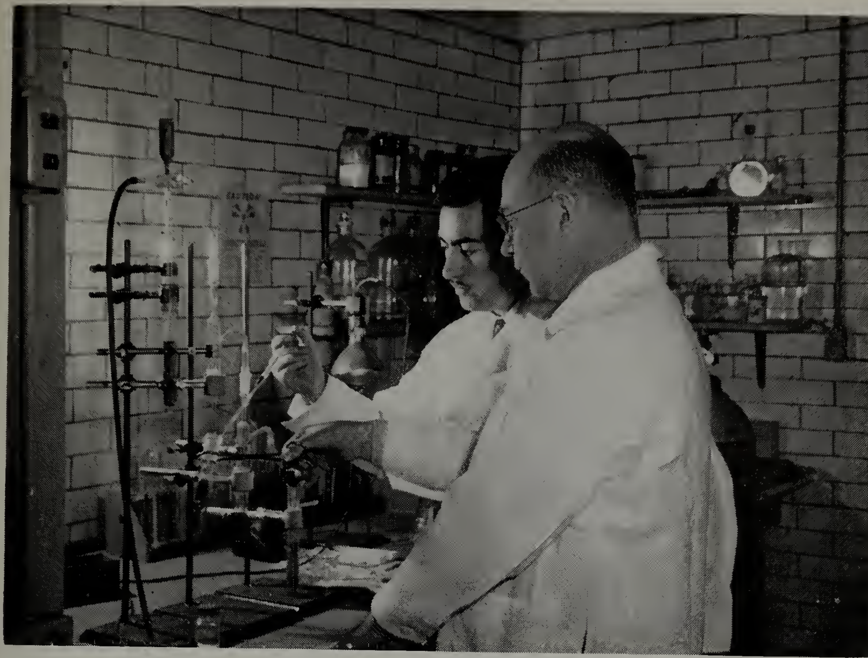
First Semester

EN	351	Statistical Methods	(3-0)3
EN	406	Fluid Mechanics	(3-2)4
EN	451	Electromechanical Engineering	(3-3)4
		*General Elective	(3-0)3
		Technical Elective	3 or 4
		Total credit hours	17 or 18

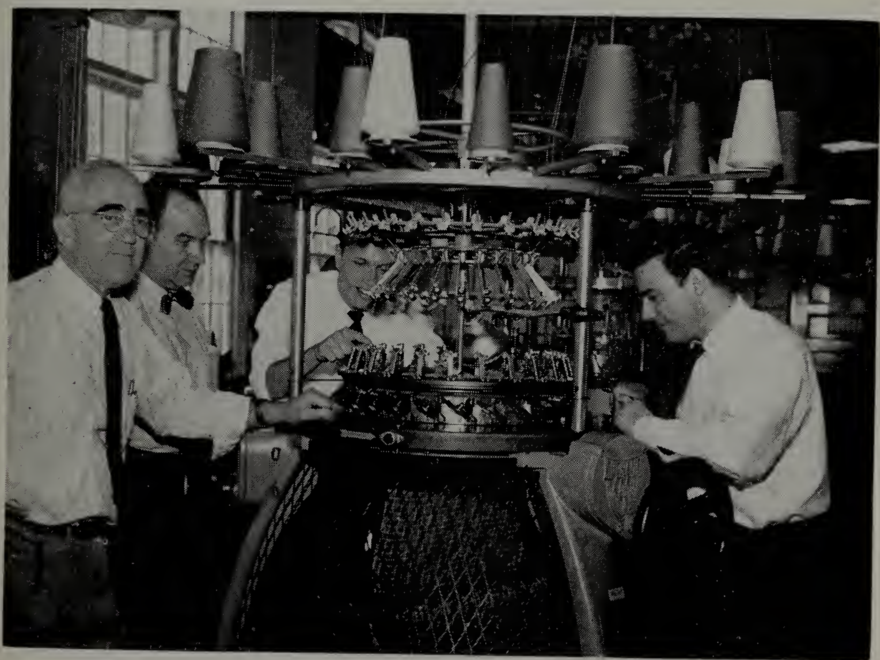
*Alternate: AS 401, Air Science (4-1)4

Technical Electives

CH	441	Chemical Engineering	(3-0)3
EN	427	Machine Design	(2-3)3
MA	403	Modern Mathematical Methods	(3-0)3
PH	543	Spectrographic Methods	(2-3)3
PH	545	X-Ray Diffraction	(2-3)3



New Field—Nuclear Research



Traditional Course—Knitting

Plastics Engineering Instruction

Air Force ROTC Band at Attention

Crucial Moment on the Court

In Paper Engineering Laboratory

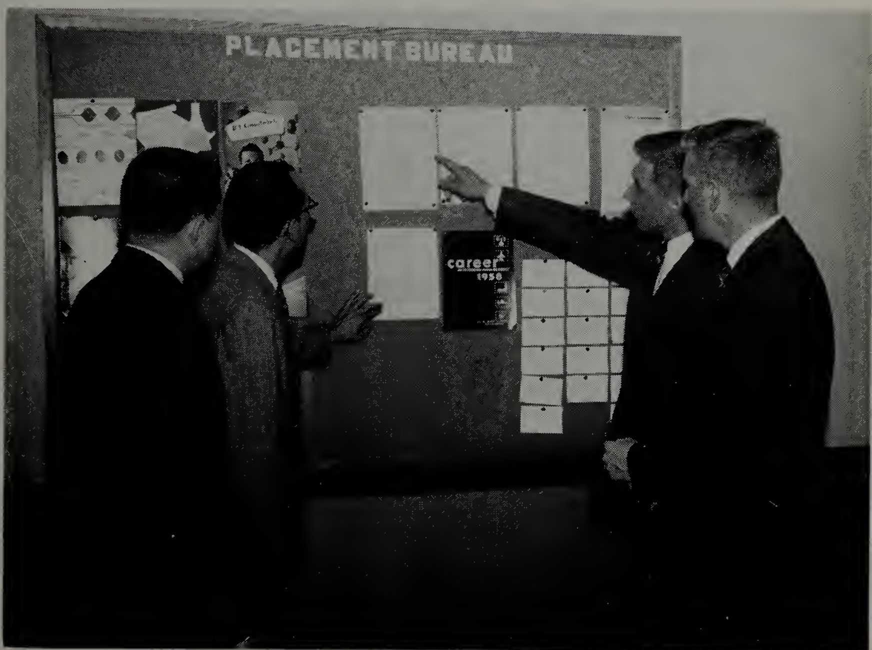
Sorority Plans in the Making

Dorm Residents at Ease

Alumni Memorial Library

Leather Engineering Project

Future Electronic Engineers



Direction from the Placement Office

Morning in the Chem Lab

Evening at the Ball

Second Semester

EN	404	Heat Transfer	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
EN	452	Electromechanical Engineering	(3-3)4
		*General Elective	(3-0)3
		Technical Electives	6 or 7
		Total credit hours	19 or 20

*Alternate: AS 402, Air Science (4-1)4

Technical Electives

EN	412	Advanced Heat Engineering	(2-3)3
EN	428	Machine Design	(2-3)3
EN	442	Air Conditioning	(2-2)2
EN	502	Statistical Quality Control	(3-0)3
EN	506	Methods of Experimental Stress Analysis	(2-3)3
MA	404	Modern Mathematical Methods	(3-0)3
PH	548	Electron Microscopy and Electron Diffraction	(2-3)3

General Electives are to be chosen as follows:

Four or more subjects must be taken from Groups 1 and 2 (below). At least two subjects must be from Group 1 and one subject from Group 2.

Group 1.

GS 101, 102, 201, 202, 213, 214, 223 or 224, 226, 301, 303, 371 or 372, 470, 472.

Group 2.

GS 222, 233, 234, 265, 266, 473, 475.

NOTE: For explanation of the Elective System, see page 57.

Leather Engineering

The Leather Engineering course has been designed to graduate engineers with a thorough understanding of the art of leather manufacturing, aware that many products of the leather industry can be improved by the application of sound and intelligent research and development. The economics, size, and scope of the leather industry warrant the careful training of individuals capable of handling its specific problems.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	205	Qualitative Analysis	(2-6)4
EN	325	Applied Mechanics	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	21

*Alternate: GS 201, Principles of Economics I (3-0)3

Second Semester

*AS	201	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	212	Quantitative Analysis	(3-6)5
EN	352	Statistical Methods	(3-0)3
LE	202	Applied Leather Analysis	(1-4)2
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: GS 202, Principles of Economics II (3-0)3

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-3)4
EN	331	Strength of Materials	(3-0)3
*GS	341	Accounting I	(3-0)3
LE	301	Leather Technology	(3-6)5
LE	303	Leather Histology	(2-4)4
		Total credit hours	19

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	334	General Colloid Chemistry	(3-0)3
LE	302	Leather Technology	(3-6)5
LE	304	Leather Microbiology	(2-4)4
		*General Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

LE	401	Leather Technology	(3-6)5
LE	405	Leather Seminar	(1-0)1
LE	411	Leather Problems	(1-6)3
PH	351	Electronic Circuits	(3-1)3
		*Two General Electives	(6-0)6
		Total credit hours	18

*AS 401, Air Science (4-1)4 may be substituted for one elective.

Second Semester

EN	344	Electrical Machinery	(3-2)4
LE	402	Leather Technology	(3-6)5
LE	404	Properties of Leather	(2-3)3
LE	406	Leather Seminar	(1-0)1
LE	412	Leather Problems	(1-6)3
		*General Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 402, Air Science (4-1)4

NOTE: For explanation of the Elective System, see page 57.

Nuclear Science and Engineering

The program in Nuclear Science and Engineering, first to be offered by a publicly supported institution in New England, is planned to give the graduates a broad engineering education, with sufficient grounding in the specialized nuclear field to enable them to accept positions of responsibility and leadership in this rapidly growing industry.

Prototype Curriculum

SOPHOMORE YEAR

Similar to curriculum in Engineering Physics

JUNIOR YEAR

First Semester		Second Semester	
Advanced Calculus	(3-0)3	Advanced Calculus	(3-0)3
Atomic Physics	(3-0)3	Intermediate Nuclear Physics	(3-0)3
Physical Mechanics	(3-0)3	Shielding and Safety	(2-2)3
Electrical Measurements	(2-3)3	Electronic Pulse Techniques	(3-3)4
Radiochemistry	(2-3)3	Physical Metallurgy	(3-0)3
Radiation Physics	(1-0)1	Radiation Physics	(1-0)1
Humanities Elective	(3-0)3	Humanities Elective	(3-0)3

SENIOR YEAR

First Semester		Second Semester	
Modern Mathematical Methods	(3-0)3	Solid State Physics	(3-0)3
Quantum Mechanics	(3-0)3	Heat Transfer	(3-0)3
Nuclear Physics	(3-0)3	Nuclear Physics	(3-0)3
Nuclear Reactor Instrumentation	(2-3)3	Reactor Studies	(2-3)3
Fluid Mechanics	(3-0)3	Nuclear Particle Instrumentation	(2-3)3
Advanced Laboratory	(0-4)1	Advanced Laboratory	(0-4)1
Elective	(3-0)3	Elective	(3-0)3

Paper Engineering

The object of the Paper Engineering course is to fit a man for work in the papermaking, paper-converting, or allied industries. A thorough training in basic chemical engineering is offered, accompanied by instruction in the theory and practice of pulp and paper manufacture and paper converting. Paper engineering involves the application of cellulose and plastics chemistry together with engineering principles to the handling of the material in the web or sheet form, as it is treated, coated, or converted into the final product.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	290	Introduction to Chemical Engineering	(3-3)4
EN	326	Applied Mechanics	(3-0)3
EN	352	Statistical Methods	(3-0)3
GS	214	Communication of Ideas	(3-0)3
		Total credit hours	19

*Alternate: General Elective

SUMMER

PA	408	Mill Inspection Trip	No credit

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-3)4
CH	333	Industrial Stoichiometry	(3-0)3
EN	331	Strength of Materials	(3-0)3
*GS	213	Technical Scientific Writing	(3-0)3
PA	301	Pulp Technology	(3-0)3
PA	303	Pulp Laboratory	(2-6)4
		Total credit hours	20

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	334	General Colloid Chemistry	(3-0)3
CH	352	Chemical Engineering	(3-0)3
PA	302	Paper Technology	(3-0)3
PA	304	Paper Laboratory	(2-6)4
		*General Elective	(3-0)3
		Total credit hours	20

*Alternate: AS 302, Air Science (4-1)4

SUMMER

PA	409	Mill Inspection Trip	No credit

SENIOR YEAR

First Semester

CH	441	Chemical Engineering	(3-0)3
EN	405	Electronic Controls and Power Circuits	(3-2)4
PA	403	Converting Technology	(3-0)3
PA	405	Converting Laboratory	(2-6)4
PA	411	Wood Chemistry	(3-0)3
		*General Elective	(3-0)3
		Total credit hours	20

*Alternate: AS 401, Air Science (4-1)4

Second Semester

CH	442	Chemical Engineering Thermodynamics	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
PA	414	Paper Problems	(2-6)4
		Two Technical Electives	6
		*General Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 402, Air Science (4-1)4

NOTE: For explanation of the Elective System, see page 57.

Plastics Engineering

The training of engineers specifically prepared to cope with the many technical and production problems found in the expanding field of plastics fabrication is the objective of the course in Plastics Engineering. Emphasis is on the engineering principles involved in the fabrication of plastics materials into useful forms rather than the chemistry involved in the manufacture of the plastics material itself. However, the curriculum involves considerably more chemistry than most engineering courses, owing to the close relationship between the physical and chemical properties of such materials. Problems of design, manufacture, and testing in the plastics industry are closely studied.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201	Organic Chemistry	(3-3)4
CH	205	Qualitative Analysis	(2-6)4
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
PL	201	Plastics Technology I	(2-0)2
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202	Organic Chemistry	(3-3)4
CH	212	Quantitative Analysis	(3-6)5
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
PL	202	Plastics Technology I	(2-0)2
		Total credit hours	20

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	331	Physical Chemistry	(3-3)4
EN	211	Machine Tool Laboratory	(1-2)1
EN	325	Applied Mechanics	(3-0)3
EN	405	Electronic Controls and Power Circuits	(3-2)4
*GS	201	Principles of Economics I	(3-0)3
PL	301	Plastics Technology II	(2-2)3
		Total credit hours	18

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	332	Physical Chemistry	(3-3)4
EN	232	Engineering Materials	(3-2)4
EN	234	Plastics Mold Design and Construction	(1-2)1
EN	332	Strength of Materials	(3-0)3
*GS	202	Principles of Economics II	(3-0)3
PL	302	Plastics Technology II	(2-2)3
		Total credit hours	18

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

CH	403	Chemistry of High Polymers	(3-3)4
PL	401	Plastics Technology III	(2-3)3
PL	403	Properties of Polymers	(2-3)3
PL	411	Plastics Seminar	(1-0)1
		*Two electives	(6-0)6
		Total credit hours	17

*AS 401, Air Science (4-1)4 may be substituted for one elective

Second Semester

CH	404	Chemistry of High Polymers	(3-3)4
EN	408	Fluid Mechanics	(3-0)3
EN	422	Industrial Instrumentation	(2-0)2
PL	402	Plastics Technology III	(2-3)3
PL	404	Properties of Polymers	(2-3)3
PL	412	Plastics Seminar	(1-0)1
		*Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 402, Air Science (4-1)4

Electives

CH	307	Atomic and Molecular Structure		(3-0)3
CH	423-424	Advanced Organic Chemistry	(3-0)	(3-0)6
EN	203	Mechanism		(2-3)3
EN	502	Statistical Quality Control		(3-0)3
EN	509 or EN 510	Advanced Statistical Methods		(3-0)3
GS	261-262	Technical German	(3-0)	(3-0)6
MA	206	Differential Equations		(3-0)3

NOTE: For explanation of the Elective System, see page 57.

Textile Chemistry

A sound foundation in basic chemistry and a knowledge of chemical applications in textiles and in textile processes are combined in the Textile Chemistry course to provide a specialized training for chemists planning to work in the textile industry or in related chemical industries producing auxiliary chemicals and fibers.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	201M	Organic Chemistry	(3-6)5
CH	211	Quantitative Analysis	(3-6)5
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	20

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
CH	202M	Organic Chemistry	(3-6)5
CH	206	Qualitative Analysis	(2-6)4
EN	212	Machine Tool Laboratory	(1-2)1
EN	352	Statistical Methods	(3-0)3
PH	206	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

CH	311	Advanced Quantitative Analysis for Textile Chemists	(2-4)3
CH	331	Physical Chemistry	(3-3)4
CH	355	Chemistry and Physics of Fibers	(3-3)4
GS	201	Principles of Economics I	(3-0)3
TE	321	Elements of Textiles: Yarns	(2-3)3
		*General Elective	(3-0)3
		Total credit hours	20

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	332	Physical Chemistry	(3-3)4
CH	356	Chemistry of Fiber Purification	(2-3)3
CH	364	Textile Colloid Chemistry	(4-0)4
GS	202	Principles of Economics II	(3-0)3
TE	334	Elements of Textiles: Fabrics	(2-3)3
		*General Elective	(3-0)3
		Total credit hours	20

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

CH	425	Organic Chemistry of Colored Substances	(2-0)2
CH	453	Theory of Dyeing	(3-4)4
TE	455	Chemical Technology of Finishing I	(2-1)2
TE	457	Chemical Technology of Finishing II	(2-1)2
TE	471	Testing of Textiles I	(2-3)3
		*Electives	6
		Total credit hours	19

*AS 401, Air Science (4-1)4 may be taken as one elective.

Second Semester

CH	422	Chemical Textile Testing	(2-3)3
CH	454	Industrial Dyeing and Printing	(2-8)4
TE	456	Chemical Technology of Finishing I	(1-2)2
TE	458	Chemical Technology of Finishing II	(1-2)2
		*Electives	6
		Total credit hours	17

*AS 402, Air Science (4-1)4 may be taken as one elective.

Recommended technical electives are: CH 333, 334, 342, 352, 403-404, 408, 409, 423-424, 431-432, 443-444, 446, 481; MA 206; PH 302, 352, 544.

NOTE: For explanation of the Elective System, see page 57.

Textile Engineering

Engineering Option

A textile engineer is one who has had a basic training in engineering to which has been added a knowledge of the manufacture of textiles, their properties and uses. The Engineering Option of Textile Engineering provides a training in mechanical engineering similar to that found in other engineering schools, plus a knowledge of textiles sufficient to prepare the individual for a position in the textile and allied industries which may involve research and engineering principles.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
EN	203	Mechanism	(2-3)3
EN	221	Applied Mechanics I	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	226	Applied Mechanics II	(3-0)3
EN	232	Engineering Materials	(3-2)4
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
		General Elective	(3-0)3
		Total credit hours	19

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	211	Machine Tool Laboratory	(1-2)1
EN	305	Thermodynamics	(3-0)3
EN	317	Applied Mechanics III	(3-0)3
EN	351	Statistical Methods	(3-0)3
PH	351	Electronic Circuits	(3-1)3
TE	381	Principles of Textile Operations I	(4-4)4
		*General Elective	(3-0)3
		Total credit hours	20

*Alternate: AS 301, Air Science (4-1)4

Second Semester

EN	316	Applied Thermodynamics	(3-3)4
EN	320	Mechanical Vibrations	(3-0)3
EN	342	Principles of Electrical Engineering	(3-2)4
TE	352N	Principles of Textile Operations II	(3-3)4
		*General Elective	(3-0)3
		Total credit hours	18

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

EN	401	Principles of Electrical Engineering	(3-2)4
EN	407	Fluid Mechanics	(3-0)3
TE	471	Testing of Textiles I	(2-3)3
TE	483	Engineering Design of Textile Structures	(3-0)3
		*One Technical Elective and one General Elective	6
		Total credit hours	19

*AS 401, Air Science (4-1)4 may be substituted for the Technical Elective.

Technical Electives

EN	427	Machine Design	(2-3)3
EN	505	Methods of Experimental Stress Analysis	(2-3)3
PH	543	Spectrographic Methods	(2-3)3
PH	545	X-Ray Diffraction	(2-3)3

Second Semester

EN	404	Heat Transfer	(3-0)3
EN	420	Industrial Instrumentation	(2-3)3
TE	482	Application of Scientific Methods to Textile Processes	(3-0)3
TE	484	Engineering Design of Textile Structures	(3-0)3
		*One Technical Elective and one General Elective	6
		Total credit hours	18

*AS 402, Air Science (4-1)4 may be substituted for the Technical Elective.

Technical Electives

EN	428	Machine Design	(2-3)3
EN	442	Air Conditioning	(2-2)2
PH	548	Electron Microscopy and Electron Diffraction	(2-3)3
TE	472	Testing of Textiles II	(2-3)3

General Electives are to be chosen as follows:

Four or more subjects must be taken from Groups 1 and 2 (below). At least two subjects must be from Group 1 and one subject from Group 2.

Group 1.

GS 101, 102, 201, 202, 213, 214, 223 or 224, 226, 301, 303, 371 or 372, 470, 472.

Group 2.

GS 222, 233, 234, 265, 266, 473, 475.

NOTE: For explanation of the Elective System, see page 57.

Textile Engineering

General Manufacturing Option

The objective of the General Manufacturing Option of Textile Engineering is to provide the textile industry with technically trained textile engineers. Students in this program are given as complete a knowledge as possible of the raw materials, machines, and processes peculiar to the manufacture of all fibers as well as a basic training in engineering and the fundamental sciences. The course prepares the students to be useful in any textile plant, regardless of fiber processed, approaching textile problems from an engineering viewpoint.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	203	Elementary Organic Chemistry	(3-0)3
EN	203	Mechanism	(2-3)3
EN	221	Applied Mechanics I	(3-0)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
		Total credit hours	19

*Alternate: General Elective

Second Semester

*AS	202	Air Science	(2-1)2
EN	212	Machine Tool Laboratory	(1-2)1
EN	226	Applied Mechanics II	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
TE	200	Textile Fibers	(4-0)3
TE	210	Fundamentals of Yarns	(2-1)2
		Total credit hours	18

*Alternate: General Elective

JUNIOR YEAR

First Semester

EN	317	Applied Mechanics III	(3-0)3
EN	403	Principles of Heat Engineering	(3-2)4
GS	213	Technical and Scientific Writing	(3-0)3
PH	351	Electronic Circuits	(3-1)3
TE	319N	Yarns: Cotton and Filament Systems	(3-3)3
		*General Elective	(3-0)3
		Total credit hours	19

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
EN	344	Electrical Machinery	(3-2)4
EN	352	Statistical Methods	(3-0)3
TE	320	Yarns: Woolen and Worsted Systems	(3-3)3
TE	332	Fundamentals of Fabrics	(4-4)4
		*General Elective	(3-0)3
		Total credit hours	18

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

EN	407	Fluid Mechanics	(3-0)3
TE	451	Technology of Finishing I	(2-1)2
TE	453	Technology of Finishing II	(2-1)2
TE	471	Testing of Textiles I	(2-3)3
TE	483	Engineering Design of Textile Structures	(3-0)3
		*One Technical Elective and one General Elective	6
		Total credit hours	19

*AS 401, Air Science (4-1)4 may be substituted for the Technical Elective.

Technical Electives

EN	427	Machine Design	(2-3)3
EN	505	Methods of Experimental Stress Analysis	(2-3)3
PH	543	Spectrographic Methods	(2-3)3
PH	545	X-Ray Diffraction	(2-3)3
TE	571	Textile Microscopy	(2-3)3

Second Semester

EN	424	Instrumentation for Textiles	(2-2)3
TE	452	Technology of Finishing I	(0-2)1
TE	454	Technology of Finishing II	(0-2)1
TE	472	Testing of Textiles II	(2-3)3
TE	482	Application of Scientific Methods to Textile Processes	(3-0)3
		*One Technical Elective and one General Elective	6
		Total credit hours	17

*AS 402, Air Science (4-1)4 may be substituted for the Technical Elective.

Technical Electives

EN	404	Heat Transfer	(3-0)3
EN	428	Machine Design	(2-3)3
EN	442	Air Conditioning	(2-2)2
PH	548	Electron Microscopy and Electron Diffraction	(2-3)3
TE	484	Engineering Design of Textile Structures	(3-0)3

General Electives are to be chosen as follows:

Four or more subjects must be taken from Groups 1 and 2 (below). At least two subjects must be from Group 1 and one subject from Group 2.

Group 1.

GS 101, 102, 201, 202, 213, 214, 223 or 224, 226, 301, 303, 371 or 372, 470, 472.

Group 2.

GS 222, 233, 234, 265, 266, 473, 475.

NOTE: For explanation of the Elective System, see page 57.

Textile Technology

This course of study is designed to equip its students with a well-rounded understanding of the theory and principles relating to the processing of textile materials. At the same time it provides the scientific basis necessary to understand and apply this technological knowledge. Basic purpose of the program is to prepare students to become competent textile technologists for eventual supervisory, administrative, or executive positions within the industry and its allied fields. To achieve this end, a comprehensive course covers the basic theory, principles, and applications of the major phases of textile manufacture utilizing all the common fibers, both natural and man-made, and all fabricating processes.

SOPHOMORE YEAR

First Semester

*AS	201	Air Science	(2-1)2
CH	203	Elementary Organic Chemistry	(3-0)3
EN	205	Mechanism	(2-2)3
MA	205	Calculus and Analytic Geometry	(4-0)4
PH	205	Physics	(3-2)4
TE	201N	Technology of Fibers	(3-1)3
		Total credit hours	19

*Alternate: GS 223, The United States since 1865 (2-0)2

Second Semester

*AS	202	Air Science	(2-1)2
EN	212	Machine Tool Laboratory	(1-2)1
GS	214	Communication of Ideas	(3-0)3
MA	206	Differential Equations	(3-0)3
PH	206	Physics	(3-2)4
TE	202N	Mechanical and Chemical Properties of Fibers	(3-0)3
TE	210	Fundamentals of Yarns	(2-1)2
		Total credit hours	18

*Alternate: GS 224, The United States since 1865 (2-0)2

JUNIOR YEAR

First Semester

EN	311	Heat and Power	(2-2)3
EN	351	Statistical Methods	(3-0)3
*GS	201	Principles of Economics I	(3-0)3
TE	311N	Woolen System Yarns	(3-3)3
TE	313	Worsted System Yarns	(3-3)3
TE	315	Cotton System Yarns	(4-4)4
		Total credit hours	19

*Alternate: AS 301, Air Science (4-1)4

Second Semester

CH	302	Introduction to Textile Chemistry	(1-3)2
*GS	202	Principles of Economics II	(3-0)3
PH	352	Electronic Circuits	(3-1)3
TE	314	Worsted System Yarns	(3-3)3
TE	316	Cotton System Yarns	(3-3)3
TE	318	Filament System Yarns	(1-1)1
TE	330	Mechanics of Fabric Design I	(4-4)4
		Total credit hours	19

*Alternate: AS 302, Air Science (4-1)4

SENIOR YEAR

First Semester

CH	401	Introduction to Textile Chemistry	(1-3)2
*GS	303	Psychology	(3-0)3
TE	431N	Mechanics of Fabric Design II	(4-4)4
TE	433	Technology of Woven Fabrics I	(3-3)3
TE	451	Technology of Finishing I	(2-1)2
TE	453	Technology of Finishing II	(2-1)2
TE	471	Testing of Textiles I	(2-3)3
		Total credit hours	19

*Alternate: AS 401, Air Science (4-1)4

Second Semester

EN	424	Instrumentation for Textiles	(2-2)3
*GS	470	Comparative Modern Governments	(3-0)3
TE	434N	Technology of Woven Fabrics II	(3-3)3
TE	436	Technology of Knitted Fabrics	(3-3)3
TE	438	Color Theory	(1-1)1
TE	452	Technology of Finishing I	(0-2)1
TE	454	Technology of Finishing II	(0-2)1
TE	472	Testing of Textiles II	(2-3)3
		Total credit hours	18

*Alternate: AS 402, Air Science (4-1)4

NOTE: For explanation of the Elective System, see page 57.

Subject Descriptions

Subjects are listed alphabetically, regardless of the department involved, under the following headings:

AS	Air Science	LE	Leather
CH	Chemistry	MA	Mathematics
EL	Electronics	PA	Paper
EN	Engineering	PH	Physics
GS	General Studies	PL	Plastics
TE	Textiles		

The number following the letter symbols is composed of three digits. The first digit of the number indicates the college year when the subject is normally presented, e.g.: GS 111 is a freshman-year subject; PA 414 is a senior-year subject. Subjects numbered 500 and above are restricted to graduate students.

First-semester subjects are designated by odd numbers and second-semester subjects by even numbers. Hyphenated numbers indicate subjects continuing throughout the year.

Following the names of the individual subjects, the number of lecture-recitation and laboratory hours is indicated within the parentheses and the credit hour is shown outside. In the case of a year course the credit shown is the total for the year.

Examples of the above coding are as follows:

(2-6)4 means 2 hours of lecture-recitation and 6 hours of laboratory for 4 credits; (2-3) (1-6)6 indicates 2 hours of lecture-recitation and 3 hours of laboratory for the first semester followed by 1 hour of lecture-recitation and 6 hours of laboratory the second semester, for a total credit of 6.

The prerequisites for the various subjects are shown in brackets, e.g., [EN 111]. No student can be officially registered in a subject until the indicated prerequisites have been satisfactorily completed.

AIR SCIENCE

AS 101-102 Air Science I (2-1)(2-1)4

Introduction to Air Force ROTC, elements and potentials of air power, air vehicles and principles of flight, the military instrument of national security, and professional opportunities in the United States Air Force. Classes in leadership and drill provide for the development in the student of the qualities of leadership and discipline essential to Air Force officers.

AS 201-202 Air Science II (2-1)(2-1)4

Introduction to the elements and potentials of air power. The course considers air power in terms of targets, weapons, aircraft, bases, and operations. Consideration is also given to the USAF Officer Career Program and the moral responsibility of Air Force leaders.

AS 301-302 Air Science III (4-1)(4-1)8

Concerns the development of certain specialized intellectual skills in the areas of military law, command and staff, problem solving, communication, and instruction in the Air Force, and certain technical skills in the areas of weather, navigation, and air base functions.

AS 401-402 Air Science IV (4-1)(4-1)8

Seminar in principles of personnel management. The framework of international politics, world powers and strategic areas, and the security problem in relation to international power clashes. Principles of warfare and a historical survey of air warfare. Briefing for commissioned service and a leadership laboratory.

CHEMISTRY

CH 101-102 General Chemistry (4-2)(4-2)8

Chemical principles and calculations. Includes the chemistry of both metallic and nonmetallic elements and of their compounds. A brief survey of organic chemistry is included in the second semester.

CH 201-202 Organic Chemistry (3-3)(3-3)8

[CH 102]

The classification, nomenclature, structure, mechanism of reaction, and behavior in bulk of important kinds of organic species. The laboratory work illustrates the experimental techniques which can be used to react, purify, characterize, and identify organic substances.

CH 201M-202M Organic Chemistry (3-6)(3-6)10

[CH 102]

Identical with CH 201-202 except that additional laboratory work in synthetic organic chemistry is given. Required for majors in chemistry.

CH 203 Elementary Organic Chemistry (3-0)3

[CH 102]

This subject enables students not majoring in chemistry to become conversant with the names, structural formulas, properties and uses of some important industrially available organic substances and with the role which organic chemistry plays in industry and engineering.

CH 205 and 206 Qualitative Analysis (2-6)4

[CH 102]

Mass action principles and systematic analysis of inorganic compounds by semi-micro technique. Offered both semesters.

CH 211 and 212 Quantitative Analysis (3-6)5

[CH 102]

The fundamental principles of quantitative analysis. The principles and calculations of gravimetric analysis, including an introduction to mineral separations as well as the analysis of soluble salts; the principles and calculations of volumetric analysis, including neutralization methods, oxidation-reduction methods, and iodometric methods. Offered both semesters.

CH 290 **Introduction to Chemical Engineering** **(3-3)4**
[CH 211]

An introductory study of the principles of material and energy balance, equilibrium, and rate of reaction. Examples are studied in the laboratory. The student is encouraged to develop his initiative and resourcefulness in obtaining experimental data, analyzing results, and communicating his findings by written and oral reports.

CH 302 **Introduction to Textile Chemistry** **(1-3)2**
[CH 102]

Lectures for the non-chemist on the various processes preliminary to dyeing. The preliminary treatments given the natural and manufactured fibers are studied as well as the action and properties of the textile chemicals used in these processes.

CH 307 **Atomic and Molecular Structure** **(3-0)3**
[CH 102]

Modern concepts of atomic and molecular structures as interpreted through emission, ultraviolet, infrared, and Raman spectra.

CH 311 **Advanced Quantitative Analysis for Textile Chemists** **(2-4)3**
[CH 211 or 212]

The examination and evaluation of chemicals utilized in the textile industry. Advanced techniques and instrumental methods are introduced for the analysis of bleaching agents, industrial water, soaps, oils, and synthetic detergents. Group projects and report writing. For students in the Textile Chemistry course.

CH 314 **Advanced Quantitative Analysis** **(2-4)3**
[CH 211 or 212]

Advanced principles and techniques of analytical separations with laboratory emphasis on some instrumental methods. The following topics will be considered: fractional precipitation methods, colorimetry, chromatography, compleximetry, potentiometric titrations, polarography, and organic precipitating agents. Group projects and report writing. For students in the Chemistry course.

CH 331-332 **Physical Chemistry**
Eng. Phys. (3-1½)(3-3)8
Others (3-3)(3-3)8
[CH 102, MA 205, PH 205]

The formulation and development of the mathematical and mechanical models of theoretical chemistry and their uses in the solution of the practical problems of chemistry and chemical

engineering. Topics included are atomic and molecular structure, states of matter, thermodynamics, thermochemistry solutions, electrochemistry, colloids, chemical equilibrium, kinetics, and photochemistry. CH 331 is for students not majoring in chemistry.

CH 333 Industrial Stoichiometry (3-0)3

[CH 211 or 212, PH 205]

A study of some important operations in the chemical industry, e.g., sulfuric acid, and in the pulp and paper industry from the standpoint of the application of reaction rate and mass and energy balance to the prediction of performance, yield, etc. Recirculatory processes are also studied.

CH 334 General Colloid Chemistry (3-0)3

[CH 331]

The approach is from the standpoint of the theoretical properties of the colloid system. Interfacial phenomena, particle kinetics, electrical properties, and viscosity characteristics are studied. The preparation of colloid solutions and the character of lyophobic and lyophilic sols, gels and emulsions are developed from the above fundamental properties.

CH 342 Organic Qualitative Analysis (1-6)3

[CH 202; CH 205 or 206]

Methods of identification of "unknown" organic substances whose properties have been previously published in the chemical literature.

CH 352 Chemical Engineering (3-0)3

[CH 102, CH 331, MA 206, PH 206]

Descriptive and quantitative information on unit conversion, dimensional analysis, materials of construction, flow of fluids, flow of heat, hygrometry, humidification, dehumidification, and drying.

CH 355 Chemistry and Physics of Fibers (3-3)4

[CH 202 and 211]

The structure and chemical reactions of linear high polymers of importance in the field of natural and synthetic fibers; the chemical and physical structure of polymers and fibers; the relation of molecular length, orientation, crystallinity, intermolecular attractions, side chains, and flexibility of polymers to the physical properties of fibers; chemical reactions of polymers and their effects on fibers.

CH 356 Chemistry of Fiber Purification (2-3)3
[CH 202 and 211]

A study of the impurities present in textile fibers and fabrics and their removal. Both natural and manufactured fibers are taken up. This subject is covered by lecture, laboratory and pilot plant work.

CH 364 Textile Colloid Chemistry (4-0)4
[CH 331]

Basic principles of surface and colloidal chemistry and their applications in industry. Special emphasis is placed on applications to the textile field: wetting, detergency, and finishing processes, as well as the colloidal behavior of the fibers themselves.

CH 401 Introduction to Textile Chemistry (1-3)2
[CH 302]

A continuation of CH 302. The application of various classes of dyes to natural and manufactured fibers. Methods of dyeing, fastness properties of different classes of dyes, and the nature and use of dyeing assistants are stressed.

CH 403-404 Chemistry of High Polymers (3-3)(3-3)8
[CH 202 and 332]

Definition and classification of high polymers; chemistry of the more important polymers including preparation, physical properties, and chemical properties; mechanism and procedures for polymerization, copolymerization, and condensation; physico-chemical investigations including molecular weight determination and distribution; the structure of high polymers including relationship of structure to properties; inter- and intra-molecular forces; states of aggregation; transition points; elasticity; visco-elastic behavior; cross-linking; plasticization (internal and external); solvent action.

CH 408 and/or 409 Advanced Studies in Chemistry Credits to be arranged

[Permission of the Chairman of the Chemistry Division and the instructor]

Advanced work in analytical, organic, inorganic, physical, or textile chemistry. Includes literature survey, laboratory work, and reports.

CH 422 Chemical Textile Testing (2-3)3
[CH 356 and 364]

Chemical methods of textile testing. Quantitative as well as qualitative determination of fiber content, finishing agents and dyestuffs. Includes optical methods of analysis and evaluation.

CH 423-424 Advanced Organic Chemistry (3-0)(3-0)6
[CH 202]

Extension of first-year organic chemistry to include additional classes of compounds and special topics. Emphasis is placed on synthetic methods including the mechanism, scope, and limitations of the important name reactions in the field of synthetic organic chemistry.

CH 425 Organic Chemistry of Colored Substances (2-0)2
[CH 201]

The relation between the structure of an organic molecule or ion and its absorption in the ultraviolet or visible spectral region. The synthesis and reactions of selected colored organic substances.

CH 431-432 Advanced Physical Chemistry (3-0)(3-0)6
[CH 314 and 332]

An extension of introductory physical chemistry for majors in chemistry and related fields. Includes additional work in chemical thermodynamics, kinetics, and equilibrium as they apply to the various chemical phenomena with emphasis on the use of chemical literature, methods of treating data, and problem-solving.

CH 441 Chemical Engineering (3-0)3
[CH 352]

A continuation of CH 352. The unit operations of evaporation, gas absorption, filtration, and washing.

CH 442 Chemical Engineering Thermodynamics (3-0)3
[CH 332]

A study of the first law of thermodynamics. Heat capacity, perfect gases, phase rule, and generalized pressure, volume, and temperature relations. An introduction to the second law.

CH 443-444 Advanced Inorganic Chemistry (3-0)(3-0)6
[CH 202 and 314]

Graduate credit allowed

Advanced chemistry of the common elements and their compounds, including coordination complexes, inorganic stereoisomerism, ion exchange, etc.

CH 446 Advanced Inorganic Chemistry Laboratory (0-3)1
[CH 202 and 314]

Inorganic preparations and advanced techniques.

CH 453 **Theory of Dyeing** **(3-4)4**
[CH 355 and 364]

Mechanisms of reactions in the dyeing of cellulose, cellulose acetate, protein, polyamide, polyester, and polyacrylonitrile fibers. Emphasizes basic physical and chemical variables affecting equilibria and rates of dyeing, diffusion and adsorption. In the laboratory, principles of transmission and reflectance spectrophotometric measurement are employed in kinetic and equilibrium studies.

CH 454 **Industrial Dyeing and Printing** **(2-8)4**
[CH 453]

A study of the technology of dyeing and printing the commercially important natural and synthetic fibers using the principal classes of dyes. Includes methods of application, color and color matching, dyestuff properties, and economics of dyeing processes. Principles of design and use of important industrial units are illustrated by pilot plant experiments. Engineering aspects of circulation, agitating, and heat exchange are considered, and the effect of these variables in the dyeing of printing processes is illustrated.

CH 461 **Microbiology** **(1-3)2**
[CH 202]

This subject considers the fundamentals of mycological and bacteriological theory briefly but in sufficient detail so that the problem of the microbiological deterioration of textiles, paper, and leather may be discussed. Methods of detecting mildewing, methods of testing textiles for mildew resistance, and bacteriological water analysis are also studied.

CH 464 **Advanced Microbiology** **(1-3)2**
[CH 461]

Work is arranged according to the particular interests of the student and consists of special projects.

CH 473 or 474 **General Biochemistry** **(2-4)4**
[CH 201-202 or permission of instructor]

The chemistry and metabolism of carbohydrates, proteins and fats, and their products.

CH 475 or 476 **General Bacteriology** **(2-4)4**
[CH 201-202 or permission of instructor]

The fundamentals of bacteriology, covering the morphology, physiology, and pure culture characteristics of bacteria.

CH 481 **Nuclear Chemistry and Radiochemistry** **(2-3)3**
[CH 332]

The theory and practice of nuclear chemistry and radiochemistry.

CH 491 **Textile Chemistry Literature Seminar** **(2-0)2**

[Permission of instructor]

A study and discussion of current textile chemistry literature, stressing the critical analysis of the subject matter.

CH 501 **Color Measurement** **(1-3)2**

[CH 422 or equivalent]

Theory and application of adsorption spectrophotometry to the qualitative and quantitative analyses of colored substances in both transparent and opaque media in the ultraviolet, visible, and near infrared ranges. Includes theories of color, vision, and subjective color evaluation.

CH 503 **Interpretation of Data** **(2-0)2**

Mathematical methods of analyzing, plotting, and interpreting experimental data. Lectures and exercises.

CH 505 **Physical Chemistry of Dyeing** **(2-3)3**

A combination of lectures, seminars, and laboratory experiments on the physicochemical principles involved in the application of dyestuffs to textile materials.

CH 507-508 **Chemistry Seminar** **(1-0)(1-0)2**

CH 512 **The Physical Chemistry of Surface-active Agents** **(2-0)2**

[CH 364]

A series of lectures on the physicochemical principles involved in the use of surface-active agents in textile processing. The surface and bulk properties of the agents are studied and related to the over-all technical properties and uses.

CH 513-514 **Physicochemical Methods** **(2-4)(2-4)6**

Theory, applications, and limitations of important physical methods of analysis used in modern research. Methods include X-ray diffraction, ultraviolet and infrared spectroscopy, and microscopy (phase, polarization, electron). Special attention is given to methods for determining the size and shape of macromolecules.

CH 521-522 **Physical Organic Chemistry** **(3-0)(3-0)6**

A study of structure, bonding, and polarization as related to organic compounds. Electronegativity, hydrogen bonding, dielectric behavior, acids and bases, catalysis, and reaction mechanisms. Both catalysis and reaction mechanisms are correlated with the theory of absolute reaction rates.

CH 523-524 **Organic Chemistry of Polymeric Species** **(3-0)(3-0)6**
[CH 202, 332, 424]

The classification, mechanism of formation, structure, and properties in bulk of polymeric organic species.

CH 525-526 **Chemistry of the Carbohydrates** **(3-0)(3-0)6**
[CH 202 and 332]

Starting with the chemistry of the simple sugars, this subject leads to a detailed study of the physical chemistry and the organic chemistry of the important polysaccharides, such as cellulose and starch, and of their industrially important derivatives.

CH 527 **Metal-Organic Compounds** **(3-0)3**

The chemistry of the important classes of metal-organic compounds including bis-arene derivatives. Includes in addition the organo-silicon, organo-boron, and organo-phosphorus classes.

CH 528 **Stereochemistry** **(3-0)3**

Concerns the fundamental concepts of optical and geometrical isomerism and the relationship of the stereostructures to the physical and chemical properties of organic compounds.

CH 529 **Heterocyclic Chemistry** **(3-0)3**

Classification, nomenclature, structure, synthesis, and utility of the more important classes of heterocyclic compounds.

CH 531-532 **Chemical Thermodynamics** **(3-0)(3-0)6**

Classical and statistical principles of thermodynamics and their application to chemical problems. The description of system states and the development of criteria for determining the spontaneity of physical and chemical changes are emphasized.

CH 533 **Statistical Mechanics for Chemists** **(3-0)3**

Mathematical introduction to statistical mechanics and applications to chemical problems.

CH 534 **Quantum Mechanics for Chemists** **(3-0)3**

Mathematical introduction to quantum mechanics and applications to chemical problems.

CH 535-536 **Advanced Topics in Physical Chemistry** **(3-0)(3-0)6**

Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

CH 537 Chemical Kinetics (3-0)3

The theoretical and empirical treatment of chemical kinetic data of both organic and inorganic chemistry as well as the methods of obtaining these data. The determination of the order of reactions, factors influencing rates, application of rate studies in establishing hypotheses for reaction mechanisms, complex reactions, and absolute rate theory.

CH 538 Rheology (2-0)2

The general principles of the deformation and flow of matter under stresses are studied qualitatively and quantitatively. Hookean and non-Hookean elasticity and Newtonian and non-Newtonian flow are related to the properties of materials, especially in the field of high polymers.

CH 541-542 Graduate Thesis Credits to be arranged

The graduate thesis is an independent investigation of a problem by the student in conference with a faculty adviser and approved by the Department Head. A clear and systematic written presentation of the results is a required part of this subject.

CH 551 or 552 Textile Testing Problems (1-3)2

[CH 422]

Special problems relating to the design and evaluation of improved analytical or testing procedures.

CH 553-554 Evaluation of Finishing Agents Credits to be arranged

A laboratory study designed to teach the use of the various test methods and instruments in evaluating the effect of finishing treatments on the tactile and end-use properties of a fabric.

CH 555-556 Textile Chemistry Seminar (2-0)(2-0)4

A series of informal discussions of current problems in research and technology in the textile chemistry field. Special investigations of the literature will be utilized to serve as a source of seminar topics.

CH 559 Instrumental Methods in Textile Research (1-2)2

The use of instruments in textile chemical research. The lectures cover the general principles of instrumentation in the various fields considered. The laboratory exercises invoke the use of specific instruments and are designed to teach the student to make a proper choice of instrumental methods in common textile chemical problems.

CH 561-562 Polymer-Chemical Principles in the Technology of Organic Construction Materials (3-0)(3-0)6

Application of polymer-chemical principles to the chemical technology of organic construction materials (orcons) such as textiles, plastics, paper, and leather. For example, it is shown how the principle of cross-linking is utilized to modify the performance properties of cotton and rayon (crease recovery), of wool (permanent pleating), rubber (vulcanization), textile finishes and plastics (curing), leather (tanning) and paper (wet strength), and how the principle of swelling is utilized to make these materials accessible to modifying agents as in finishing, dyeing, and plasticization.

CH 563-564 Special Topics in the Chemistry and Technology of Manufactured Fibers (2-0)(2-0)4

[CH 355]

Important considerations in the areas of synthesis and structure of fiber-forming polymers, conversion of polymers into fiber forms, and fiber properties and applications.

ELECTRONICS

EL 201-202 Introductory Circuit Theory (4-0)(3-0)7

[PH 104 and MA 108; EL 205-206 and 207-208 taken concurrently]

An introduction to the study of the mathematical and physical aspects of electric circuits in which radiation in the form of electromagnetic waves does not play a major role. Resistive circuits, Kirchhoff's laws, Thevenin's theorem, reciprocity of simple circuits, sinusoidal steady-state behavior, vector diagrams, resonance, transients in alternating current circuits, loci of complex functions, polyphase systems, and an introductory discussion of simple nonlinear circuits.

Text: Guillemin, *Introductory Circuit Theory.*

EL 203-204 Elementary Electricity and Magnetism Laboratory (0-3)(0-3)2

[PH 104; EL 201-202 taken concurrently]

The purpose of this subject is to give the student a working knowledge of the use of common electrical devices and measuring equipment as well as practice in the preparation of circuit drawings, the writing of technical reports, and the analysis of the precision of measurements. Some attention is given to the practical techniques useful in the construction of electrical equipment and accessories.

Among the topics considered in the laboratory are: measurements of resistance, capacitance, inductance and impedance; d.c. and a.c. bridge circuits; magnetic measurements; characteristics of vacuum tubes and other nonlinear devices; elementary vacuum tube circuits; a.c. and d.c. motors, and transformers.

Texts: Stout, *Basic Electrical Measurements;* Dunn and Barker, *Electrical Measurements Manual.*

EL 205-206 — Introductory Field Theory — (4-0)(3-0)7

[PH 104 and MA 108; MA 205 and 206 taken concurrently]

The fundamental laws of electricity and magnetism presented from the point of view of field theory. Free use is made of the calculus. Topics in the first semester include electrostatics, steady currents and their magnetic fields, induced electromotive forces and inductance, elementary alternating current circuits, and time-dependent magnetic fields. In the second semester the following topics are studied: electromagnetic waves in free space, on wires, and in material bodies; behavior of electrons in metals, thermionic emission, dielectric and magnetic properties of matter, geometrical optics, physical optics, atomic structures, and topics in modern physics.

Text: Frank, *Introduction to Electricity and Optics,* 2nd edition.

EL 210 — Electronic Circuits — (3-0)3

Characteristics of electronic tubes; graphical solutions for circuits containing nonlinear elements; linear equivalent circuits; combinations of resistive, capacitive, and inductive elements; response of basic circuits to simple wave forms.

Text: Corcoran and Price, *Electronics.*

EL 305-306 — Electronics Laboratory — (0-4)(0-4)4

[EL 202, 204, 206, and 210]

The purpose of this subject is to give the student a good working knowledge of a number of electronic circuits and the techniques of measurement for evaluating their performance. A number of these circuits are assembled by the student. Further training is provided in the analysis and reporting of experimental work. Development of the student's initiative, resourcefulness, and independent judgment is encouraged.

Text: Reed, Wagner and Corcoran, *Electrical Communications Experiments.*

EL 307-308 — Electromagnetic Devices and Machinery — (3-0)(3-0)6

[EL 202, 206; MA 206; EL 311-312 taken concurrently]

Dimensional analysis, free and forced response of dynamic systems, electromechanical analogies; electromagnetic, piezoelectric,

magnetostrictive, electrothermal, and electromechanical devices; indicating and recording equipment, electrical computers, and fractional horsepower motors.

EL 309 Physical Basis for Electronic Engineering (3-0)3

[EL 206, MA 206]

Physical concepts and phenomena forming the basis for electronic engineering from the microscopic and macroscopic viewpoints. The electron, atoms and molecules, extranuclear atomic structure, nuclear structure, structure and behavior of metals and semiconductors, magnetic properties of matter, low-temperature phenomena, radioactivity, nuclear reactions, nuclear fission, applications of nuclear physics.

Texts: Martin, *Physical Basis for Electrical Engineering;* Van Name, *Modern Physics.*

EL 310 Electromagnetics (3-0)3

[EL 202, 206, 311; EL 312 taken concurrently; MA 206]

Electricity and magnetism are presented from the field theory point of view. Vector analysis is used throughout and Maxwell's equations are introduced early in the course. The topics covered include the static electric field in polarizable and conducting media, static magnetic fields of steady electric currents and ferromagnetic materials, time-changing electric and magnetic fields, magnetic induction, and boundary value problems associated with static fields.

Text: Kraus, *Electromagnetics.*

EL 311-312 Engineering Mathematics (4-0)(4-0)8

[MA 206]

Ordinary differential equations, Laplace transformation, numerical methods of solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations, partial differential equations of mathematical physics, and complex variable theory.

Text: Hildebrand, *Advanced Calculus for Engineers.*

EL 321 Mechanics (3-0)3

[MA 206]

Vector formulation of kinematics; Newton's formulation; particle motion; motion of a group of particles; the Lagrange formulation; Hamilton's formulation. These expositions provide a development of vector calculus and an introduction to dyadics and to variational calculus.

Text: F. W. Constant, *Mechanics.*

EL 322 **Thermodynamics** **(3-0)3**

[MA 206]

Systematic exposition of the first and second laws of thermodynamics; consequences of these principles in processes involving mechanical, electrical, magnetic, chemical, and thermal energy exchanges. An introduction to kinetic theory and statistical descriptions of gases and solids.

Text: Sears, *Thermodynamics, Kinetic Theory, and Statistical Mechanics.*

EL 323 **Electronic Circuits** **(3-0)3**

[EL 210]

A continuation of EL 210. Amplifiers; oscillators; clamping, clipping, and trigger circuits; voltage-regulating circuits, multivibrators; and counting circuits.

Text: Corcoran and Price, *Electronics*

EL 324 **Network Analysis** **(3-0)3**

[EL 202]

The formulation of general network equations and the development of various equivalent circuits and circuit theorems. The transient behavior of linear networks, characteristics of wave filters, circuits having continuously distributed constants, and other coupling networks.

Text: Van Valkenburg, *Network Analysis.*

EL 401-402 **Servomechanisms** **(3-0)(3-0)6**

[EL 210 and 312]

A survey of industrial electronic control systems. Among the topics considered are: selsyns, amplidynes, regulators, servomechanisms, magnetic amplifiers, saturable reactors, inverters, high-current rectifiers, and high-voltage machines.

Texts: Brown and Campbell, *Principles of Servomechanisms;* Nixon, *Principles of Automatic Control.*

EL 403-404 **Microwave Electronics** **(3-0)(3-0)6**

[EL 210, 310, and 312]

Practice in the analysis of electronic systems. Beginning with zero frequency circuits, a study is made of the modifications required to give proper behavior as the frequency is increased. Among the topics considered are: radio frequency circuits; television circuits; amplitude, frequency, and pulse modulation; elements of electromagnetic theory, antennas, waveguides, microwave generators and receivers.

Texts: Reich *et al., Microwave Theory and Techniques;* Panofsky and Phillips, *Classical Electricity and Magnetism.*

EL 405-406 **Communication Electronics** **(3-0)(3-0)6**
[EL 210 and 323]

Theory and application of thermionic tubes and transistors in amplifiers, oscillators, modulators, and detectors operating class A and in the switching mode. Principles of television communication.

Text: Martin, *Electronic Circuits.*

EL 407-408 **Pulse and Digital Circuits** **(3-0)(3-0)6**
[EL 202, 210, and 323]

The response of linear networks, both active and passive, to the types of wave forms commonly encountered in pulse circuits. The effects of nonlinearities of tubes and transistors on wave form transmission. Wave form generating circuits and other fundamental building blocks are analyzed in detail. Basic circuits are considered when assembled into pulse and digital systems.

Text: Millman and Taub, *Pulse and Digital Circuits.*

EL 409-410 **Electronic Projects Laboratory** **(0-4)(0-4)4**
[EL 306]

In this subject the student is given the opportunity to develop, construct, study, modify, and test electronic components and systems. He is expected to carry out his investigations more or less independently. Original investigations are encouraged but not required. The careful preparation of technical reports on the experimental work is emphasized. Where practicable, the student is expected to write his reports using the style of either the *Journal of the Institute of Radio Engineers* or the *Review of Scientific Instruments.*

EL 411-412 **Applied Electronics Laboratory** **(0-4)(0-4)4**
[EL 306 and 310]

The purpose of this subject is to give the student an experimental familiarity with the nature, application, and performance of various electronic devices. Emphasis is given to the preparation of good technical reports.

Text: Terman and Petit, *Electronic Measurements.*

EL 429-430 **Special Topics in Electronics** **(3-0)(3-0)6**

An analytical consideration of special topics of importance in the field of electronics.

EL 433-434 **Solid State Physical Electronics** **(3-0)(3-0)6**
[EL 312]

A physical interpretation of the properties of materials in terms of their dielectric constant, magnetic permeability, electrical conductivity; dielectric, ferroelectric, piezoelectric materials; dia-

magnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferrimagnetic materials; metals, semiconductors, insulators.

Electrical engineering devices whose performances are described in terms of the above properties.

Texts: Van der Ziel, *Solid State Physical Electronics;* A. J. Dekker, *Electrical Engineering Materials;* H. W. Katz, *Solid State Magnetic and Dielectric Devices.*

EL 435-436 Instrumentation (3-0)(3-0)6

[EL 210]

The basic principles of the science of measurement by electronics. Measurement of electrical quantities by electronic methods. The theory and methods of transducers for converting nonelectrical quantities into some electrical signal that may be measured by electronic methods.

EL 437 Introduction to Scientific Research (2-0)2

A survey of general principles, techniques, and guides for procedure which successful investigators in various fields of science have found helpful.

Text: Wilson, *An Introduction to Scientific Research.*

EL 440 Experimental Techniques (1-1)1

Experimental studies of heat treatment, hardenability, soft and hard soldering, glass blowing, applied vacuum techniques.

EL 501-502 Mathematical Methods for Engineers (3-0)(3-0)6

Elements of function theory, differentiation, integration, space geometry, functions of a complex variable, residues and complex integration, and applications. Algebra of linear equations, vector and tensor analysis, orthonormal functions, integral equations, and variational methods.

Texts: Smith, *Mathematical Methods for Scientists and Engineers;* Page, *Physical Mathematics.*

EL 503-504 Introduction to Theoretical Physics (3-0)(3-0)6

The student is introduced to the analytical methods of theoretical physics. The major emphasis is placed on prequantum physics. The following topics are covered: the Lagrangian and Hamiltonian formulations of analytical mechanics; special relativity; elasticity and hydrodynamics, kinetic theory, thermodynamics, and statistical mechanics; electricity and magnetism from the field-variable point of view; Maxwell's equations; and atomic spectra and structure.

EL 505-506 Microwave Electronics (3-0)(3-0)6

Elements of electromagnetic theory, transmission lines, impedance matching, waveguides, antennas, microwave oscillators and amplifiers, klystrons, magnetrons, and travelling wave tubes.

Texts: Reich *et al., Microwave Theory and Techniques;* Reintjes and Coate, *Principles of Radar;* Panofsky and Phillips, *Classical Electricity and Magnetism.*

EL 507-508 Intermediate Solid State Electronics (3-0)(3-0)6

An intensive study of selected topics in solid state electronics.

Texts: Shockley, *Electrons and Holes in Semiconductors;* Slater, *Quantum Theory of Matter;* Peierls, *Quantum Theory of Solids.*

EL 509-510 Transients in Electromechanical Systems (3-0)(3-0)6

Training in the formulation and solution of ordinary and partial differential equations which arise in the treatment of mechanical, acoustical, thermal, and electrical systems. Extensive use is made of modern operational mathematical techniques.

Text: Gardner and Barnes, *Transients in Linear Systems.*

EL 511-512 Dynamic Control Analysis (3-0)(3-0)6

The basic principles of electronic devices used for control and measurement in applied science and engineering.

Text: Truxal, *Automatic Feedback Control System Synthesis.*

EL 513-514 Electromagnetic Theory (3-0)(3-0)6

Maxwell's equations, stress and energy, the electrostatic field, the magnetostatic field, plane waves in isotropic media, cylindrical waves, spherical waves, radiation, and boundary value problems.

Text: Stratton, *Electromagnetic Theory.*

EL 515-516 Elementary Quantum Mechanics (3-0)(3-0)6

The postulational formulation of quantum mechanics. The basic theory is developed both in the operator and matrix formulations.

Texts: Schiff, *Quantum Mechanics;* Persico, *Fundamentals of Quantum Mechanics.*

EL 517-518 Solid State and Modern Physics for Engineers (3-0)(3-0)6

Elements of electronics, special theory of relativity, atomic structure of matter, quantum mechanics, X-rays, molecular structure and molecular spectra, low-temperature phenomena, natural

and induced radioactivity, nuclear fission, cosmic rays and mesons, elements of crystal physics, specific heats, alloys of metals, elastic and plastic properties of solids, rupture and fatigue of solids, thermal diffusion, electron theory of metals and alloys, thermal and electrical properties of solids, energy levels in solids, cohesion in solids; magnetic, paramagnetic, and diamagnetic properties of solids; magnetic moments and resonance, transistor physics, semiconductors, and electron diffusion in metals.

Texts: Kittel, *Solid State Physics;* Slater, *Quantum Theory of Matter;* Peierls, *Quantum Theory of Solids.*

EL 529-530 Network Synthesis (3-0)(3-0)6

The formulation of the fundamentals of network theory. Establishing realizability conditions and synthesis techniques for various classes of networks and network functions. Methods are developed for realizing one or more networks whenever a function of the given class is prescribed.

Text: Balibanian, *Network Synthesis.*

EL 531-532 Seminar in Electronics (1-0)(1-0)2

Discussion by staff members and students of current journal publications and topics of current interest in electronic science, electronic engineering, and related areas of applied physics.

EL 533-534 Special Problems in Electronics

The purpose of this subject is to give the student an opportunity for individual study, under the direction of a staff member, of topics in or related to electronic engineering.

EL 535-536 Graduate Research

Supervised research on some problem in electronic science, electronic engineering, or in certain areas of applied physics. The results of the research are to be embodied in a thesis acceptable to the departmental committee on graduate study.

ENGINEERING

EN 113 Engineering Graphics (0-3)1

Communication by graphic representation—orthographic and pictorial. Charts and graphs. Freehand and instrumental multiview drawing, dimensioning, engineering geometry, isometric sketching.

EN 114 Engineering Graphics (0-3)1

[EN 113]

The use of graphics in the solution of problems. Visualization by descriptive geometry, and its exercise in vector geometry and intersections. Graphical calculus, nomography, and empirical equations.

EN 203 or 204 Mechanism (2-3)3

The basic principles of kinematics, in which the wide variety of process machinery available furnishes many specific examples. Frequent use of these mechanisms is made in the development of the subject. Some of the important topics covered are the following: rolling cylinders and cones, gearing, gear train design, epicyclic gear trains, flexible connectors including stepped pulley and cone design, cam design, linkages, and miscellaneous mechanisms.

EN 205 Mechanism (2-2)3

Similar to EN 203, except that in the laboratory time, particular study is made of textile mechanisms.

EN 211 or 212 Machine Tool Laboratory (1-2)1

The objective of this subject is to give the student an insight into the processing of metals through lectures and practical laboratory applications covering the basic machine tools such as the lathe, shaper, drill-press, and milling machine, and also the uses of measuring instruments, threads, and gears. Lectures and demonstrations cover topics such as pattern work, foundry practice, die-casting, welding, and forging.

EN 221 or 222 Applied Mechanics I (3-0)3

[MA 108, PH 103]

The fundamentals of statics including such topics as force systems, laws of equilibrium, centers of gravity, moments of inertia, and analysis of stresses in framed structures.

EN 225 or 226 **Applied Mechanics II** **(3-0)3**

[EN 221; MA 206 taken concurrently]

The principles of rectilinear and curvilinear translation, rotation, and plane motion; Newton's laws, D'Alembert's principle. Work and energy, impulse and momentum, mechanical vibrations.

EN 232 **Engineering Materials** **(3-2)4**

[PH 103]

The manufacture, properties, and uses of important ferrous and nonferrous metals; hot and cold processing, alloying, heat treatment; also the properties and use of nonmetallic engineering materials such as timber, cement, concrete, rubber, plastic, and mechanical fabrics.

EN 234 **Plastics Mold Design and Construction** **(1-2)1**

[EN 211 or 212]

The purpose of this course is to acquaint plastics engineering students with the basic principles of mold design and construction in addition to machining and finishing operations of plastics. Sufficient laboratory time is provided to allow for the design and construction of simple molds.

EN 303 **Electrical Circuits** **(3-2)3**

[MA 206, PH 205]

Principles of electric circuit analysis by the use of the mathematical complex-plane and operational methods: Ohm's and Kirchhoff's laws, network theorems, Fourier analysis, and the Laplace transformation. Transient and steady-state behavior, resonance, magnetic coupling; the concept of equivalent circuits, and examples of nonlinear circuits.

EN 305 **Thermodynamics** **(3-0)3**

[MA 205, PH 104]

The thermodynamic system, the first law of thermodynamics, internal energy. Open and closed systems, steady flow, reversibility. The second law of thermodynamics, entropy, availability. The pure substance, the perfect gas; mixtures of gases and vapors.

EN 307 **Surveying and Structures** **(3-3)4**

[EN 221]

The fundamental principles of plane surveying, topographic surveying and mapping; principles of structural engineering; algebraic and graphical analysis of forces; calculation of allowable floor loads, stresses in beams; and allowable loads on columns.

EN 308 **Structures** **(3-0)3**
[EN 307]

Rigid frames analysis, wind stresses, stresses in riveted trusses, reinforced concrete structures, footings, foundations.

EN 309 **Metals Processing** **(2-2)3**
[EN 211 or 212]

Modern methods of manufacture including casting, forging, metal cutting and turning, spinning, welding. Testing for hardness and tensile strength; shrink fits, soldered and welded joints. Survey of current technical literature and special topic assignments.

EN 311 **Heat and Power** **(2-2)3**
[PH 205]

Similar to EN 403 but briefer and designed for those not majoring in engineering.

EN 313 or 314 **Advanced Mechanism** **(2-2)3**
[EN 203]

The graphical and mathematical analyses of advanced mechanisms found in various machines. The forces in, and velocities of, the various members of the mechanism are determined from actual data taken from the machines by the student. The subject is terminated with a problem in the design of a mechanism.

EN 316 **Applied Thermodynamics** **(3-3)4**
[EN 305]

Applications of the basic principles of thermodynamics, properties of steam and its utilization, and the combustion of fuels. A treatment of steam-generating units, turbines, and pumps.

EN 317 or 318 **Applied Mechanics III** **(3-0)3**
[EN 221, MA 206]

Stress, strain, Hooke's law. Shearing stress, riveted and welded connections. Combined stresses, Mohr's circle. Shearing force and bending moment. Beam stresses, normal bending, deflections. Simple torsion, column theory.

EN 319 or 320 **Mechanical Vibrations** **(3-0)3**
[EN 226]

Kinematics of vibration; systems with one degree of freedom, two degrees of freedom, many degrees of freedom; multicylinder engines, rotating machinery, self-excited vibrations; systems with nonlinear characteristics.

EN 325 or 326 **Applied Mechanics** **(3-0)3**
[MA 108, PH 103]

The fundamentals of statics, including such topics as force systems, laws of equilibrium, friction, centers of gravity, moments of inertia, and an introduction to dynamics.

EN 328 **Strength of Materials** **(3-0)3**
[EN 325]

Principles of the strength of materials with special emphasis on their applications to plastics. Includes such topics as bending and shearing stresses, torsion, compound beams and columns, reversals of stress, impact, vibrations, stress analysis by strain gage methods, concepts of creep and relaxation.

EN 331 or 332 **Strength of Materials** **(3-0)3**
[EN 221 or 325]

This subject covers such topics as stress fundamentals, strain bending moment and deflection, beam design, torsion, columns, combined stresses, reversals of stress, and impact.

EN 335 or 336 **Physical Metallurgy** **(3-0)3**
[MA 206, PH 206]

Atomic structure, crystal structure and imperfections, phases and transformations, phase diagrams, electrical and magnetic properties related to structure, thermal and optical properties, elasticity and plasticity in metals, diffusion, recovery, recrystallization, grain growth, hardening, and heat treatment.

EN 342 **Principles of Electrical Engineering** **(3-2)4**
[PH 351]

The greater part of the subject is devoted to direct-current generators and motors with a study of their construction and characteristics. Three-phase circuits and alternators are also considered. The accompanying laboratory work illustrates the various methods of measuring polyphase power and of determining the characteristics of direct-current generators and motors.

EN 344 **Electrical Machinery** **(3-2)4**
[PH 351 or 352 taken concurrently]

A condensation of EN 342 and EN 401.

EN 351 or 352 **Statistical Methods** **(3-0)3**
[MA 205]

The application of modern statistical techniques to the treatment of experimental data. Characteristics of distributions, significant differences, linear correlation, and analysis of variance. Introduction to the planning of industrial experiments.

EN 401 Principles of Electrical Engineering (3-2)4

[EN 342]

Alternator regulation, parallel operation, single-phase and three-phase transformers, induction motors and their applications, starting devices for motors, synchronous motors, and correction of power factor.

EN 402 Electrical Control Systems (3-3)4

[EN 401]

The operation of simple servomechanisms, potentiometers, synchros and related error detectors, double-speed synchronizing networks, demodulators and modulators, electronic amplifiers, servomotors, magnetic and rotating amplifiers, design of servomechanisms, tests of servomechanisms.

EN 403 Principles of Heat Engineering (3-2)4

[MA 205, PH 104]

The basic principles of thermodynamics, properties of steam and its utilization in manufacturing processes, and the combustion of fuels. A brief treatment of steam engines, turbines, and pumps. Special consideration is given to the use of steam in manufacturing processes.

EN 404 Heat Transfer (3-0)3

[MA 205, PH 104]

Modes of heat transfer; conduction, radiation, forced and free convection. Dimensional analysis. Heat transfer to boiling liquids and condensing vapors. Over-all transfer of heat. Finned surfaces and heat exchangers. Transient conduction.

EN 405 Electronic Controls and Power Circuits (3-2)4

[PH 205]

Power requirements in single-phase and three-phase power circuits; operating characteristics of various types of direct-current and alternating-current motors and their manual and automatic controls; industrial electronics including photoelectric relays, time delay relays, motor control, and side register control as applied in the plastics industry.

EN 406 Fluid Mechanics (3-2)4

[MA 205, PH 205]

Properties of fluids; statics of fluids; flotation; relative equilibrium; dynamics of fluids, Bernoulli's theorem, measurement of velocity and pressure; cavitation; flow of viscous fluids; Reynolds' number; flow in pipes; flow with free surface; critical depth; weirs;

orifices and nozzles; impulse and momentum in fluids; resistance of immersed and floating bodies. Froude's number, boundary layer; dynamics of compressible fluids; Mach's number; dynamical similitude and Pi theorem.

EN 407 or 408 Fluid Mechanics (3-0)3
[MA 205, PH 205]

Similiar to EN 406 but without laboratory work.

EN 411 or 412 Advanced Heat Engineering (2-3)3
[EN 316]

Elements of the design of power plants and heating systems, internal combustion engines, and related subjects.

EN 419 or 420 Industrial Instrumentation (2-3)3
[PH 205]

Similar to EN 422 with the addition of three hours of laboratory per week.

EN 422 Industrial Instrumentation (2-0)2
[PH 205]

Modern methods of measurement and control of the more common process variables such as temperature, pressure, liquid level, and fluid flow; response characteristics of mechanical, electric and electronic instruments; modes of control; associated mechanical and electrical mechanisms; characteristics of final control elements; closed-loop control systems; process characteristics and their effects upon the selection of the correct mode of control.

EN 424 Instrumentation for Textiles (2-2)3
[PH 352]

A study of indicating and recording instruments used to measure such common textile process variables as pressure, temperature, humidity, liquid level, fluid flow, etc. Response characteristics of mechanical, electrical, and electronic systems, and process characteristics and their effects upon the selection of the correct mode of control.

EN 427-428 Machine Design (2-3)(2-3)6
[EN 317]

The application of engineering principles to the design of machine elements including working stresses, shafting, springs, screws, belts, clutches, brakes, lubrication, bearings, gearing, press and shrink fits, miscellaneous machine elements, and optimum design considerations.

EN 433 Manufacturing Tools and Methods (3-0)3

Not offered in 1959-60

Designed to familiarize students with manufacturing methods and machines in general industrial work. Plant layout and planning; machine tool performance; power transmission and control; product evaluation and quality control.

EN 441 or 442 Air Conditioning (2-2)2

[PH 205]

The fundamental principles of heating, ventilating, and refrigeration. The laboratory consists of design problems in the air conditioning of industrial buildings.

EN 451-452 Electromechanical Engineering (3-3)(3-3)8

[EN 303 and 344]

A study of methods of measurement and control in electromechanical systems. Servomechanisms, analog and digital computers, switching circuits and motor controls. The characteristics of various types of electromechanical transducers and their associated circuitry as employed in the measurement of such quantities as acceleration, velocity, displacement, stress, strain, thickness, mass and weight, and frequency and intensity of sound; also in inspection devices and in such applications as the generation and use of ultrasonic waves.

EN 501 or 502 Statistical Quality Control (3-0)3

[EN 351 or 352]

A study of the various types of control charts for maintaining the quality of manufactured products and the several types of sampling plans for the reduced inspection of manufactured products and of raw materials. Applications of the foregoing statistical techniques to various industries are considered.

EN 505 or 506 Methods of Experimental Stress Analysis (2-3)3

[EN 317, MA 205, PH 205]

An introduction to some of the experimental techniques used in stress analysis. Photoelasticity, electrical strain gages, brittle coating, and mechanical gages are considered in relation to the analysis of both static and dynamic stresses. Special attention is given to the application of these techniques in the study of industrial structures and machinery.

EN 509 or 510 Advanced Statistical Methods (3-0)3

[EN 351 or 352]

A continuation of EN 351 or 352 with particular study of the more advanced statistical techniques as applied to the design of industrial experiments and to the analysis and interpretation of the resulting data.

EN 591 and 592 **Graduate Thesis** **Credits to be arranged**

Each candidate for a graduate degree in engineering is required to submit a thesis which shows ability and originality in the solution of a research project. May be repeated for credit.

EN 593-594 **Graduate Seminar** **(1-0)(1-0)2**

Required of all graduate students in engineering.

GENERAL STUDIES

GS 101-102 **Elements of Political and Economic Geography** **(2-0)(2-0)4**

A survey of the factors influencing the contemporary relations of nations. Population, industry, resources, climate, and political structure are studied through readings, discussion, and class lectures.

GS 111 **English Composition** **(3-0)3**

Training in the basic principles of clear and correct composition. Concentration on paragraph construction and development leading to effective expository writing. Introduction to the elementary research techniques of outlining, note taking, footnoting, compiling bibliographies, and using the library. Analysis and discussion of the composition and content of collateral reading. Regularly assigned written exercises and individual conferences.

GS 112 **English Composition** **(3-0)3**

Training in the composition of extended written exercises. Emphasis on analysis and evaluation. A guided research project. Critical analysis and discussion of collateral reading in the sciences and humanities. Regular individual conferences.

GS 121 or 122 **Perspective Drawing** **(1-1)1**

A mechanical method of representing objects of three dimensions, showing correct proportions as they appear to the eye.

GS 131 or 132 **Freehand Drawing** **(0-3)1**

Freehand drawing of objects of different textures. Visual training and graphic expression to build a drawing vocabulary which will aid in advanced drawing subjects.

GS 201 **Principles of Economics I** **(3-0)3**

The foundations and nature of economic principles. National income, money and banking, and a brief survey of economic history.

GS 202 **Principles of Economics II** **(3-0)3**

[GS 201]

Price and production theories, the distribution of income, and comparative economic systems.

GS 209 or 210 **Speech** **(2-0)2**

[GS 112]

The aim of this subject is to achieve effective delivery of various types of speech. All kinds of delivery are studied and analyzed.

GS 211 or 212 **Business English** **(2-0)2**

[GS 112]

Analysis and practice in letter writing and a study of the basic forms of technical exposition, forming a background for report writing in advanced courses and in industrial activity.

GS 213 **Technical and Scientific Writing** **(3-0)3**

Thorough grounding in the special demands of technical and scientific exposition, including reports, technical and business correspondence, and research papers, supplemented by readings in technical and scientific fields. Practice in oral communication in connection with the presentation of abstracts, summaries, and reports based on readings and on problems coordinated with the written requirements of other departments.

GS 214 **Communication of Ideas** **(3-0)3**

Study and interpretation of assigned readings in the several forms of nontechnical writing, such as the novel, short story, drama, essay, and poetry, with the purpose of familiarizing the student with the methods by which thought is communicated. Skill in presenting ideas is developed through written assignments, including essays or reports of an analytical or critical nature, through oral expression by panels and committees, and through individual oral presentation of assigned subjects.

GS 222 **Appreciation of Literature** **(3-0)3**

The principles of literary appreciation and criticism. An analysis of prose and poetical selections, with directed investigation of the various literary appeals—the intellectual, the sensory, the emotional, the aesthetic, the imaginative, and the philosophical.

GS 223-224 **The United States since 1865** **(2-0)(2-0)4**

A survey of the advancement of the American people from the Reconstruction Era to the present.

GS 226 World History since 1900 (3-0)3

Particular attention is paid to the years 1919-1939 and such topics as the rise of new states; the origin and development of new concepts of nationalism, racism, and other phenomena; the alignment of world powers for World War II; and the role of the United States in mid-twentieth-century reconstruction.

GS 233 Comparative Literature (3-0)3

A consideration of at least six classics of western civilization as keys to the development of literary types. An attempt to deduce standards of critical judgment. Class discussions and critical papers.

GS 234 Shakespeare (3-0)3

Shakespeare's chief tragedies, comedies, and chronicles. Lectures and discussions on Shakespeare and the nature of man. Critical papers.

GS 261-262 Technical German (3-0)(3-0)6

The basic elements of German, leading to the development of reading ability in scientific German.

GS 263-264 Technical French (3-0)(3-0)6

The basic elements of French, leading to the development of reading ability in scientific French.

GS 265-266 Elementary Russian (3-0)(3-0)6

An introduction to the study of the Russian language to develop basic grammar and reading knowledge.

GS 301 Economic Development of the United States (3-0)3

A brief review of the background of the present economic system and an intensive study of the influence of science and technology upon our economic development. The central theme is the dominant role of the science and technology of our time in present-day American life.

GS 302 Modern Labor Problems (3-0)3

The backgrounds of present-day labor organizations and modern labor law with particular emphasis upon current labor problems in the United States. The major objective of the semester is to familiarize upperclass students with the procedures and techniques of collective bargaining with special attention to the formulation and administration of various types of labor contracts.

GS 303 Psychology (3-0)3

The place of psychology in the life of the individual and society. A survey of the psychological basis of behavior and attitude as related to personal, industrial, and community experiences.

GS 305 — Sociology — (3-0)3

A consideration of the basic principles of sociology, including the development of man, culture, culture and personality, social organization and structure, groups and group life, social relations, collective behavior, social change, and social institutions.

GS 307 — Principles of Finance and Banking — (3-0)3

[GS 202]

The monetary and banking system in the United States. The financial organization of business. The role of the Federal Reserve System and the Treasury in terms of monetary and fiscal policy.

GS 311 — Economic Statistics — (3-0)3

Basic concepts of the statistical method with special emphasis on those approaches of most interest to the student of management. Topics covered include measures of central tendency, graphic methods, dispersion, skewness, sampling, normal curve, index numbers correlation, time series, secular trend, seasonal variation, business cycle, and statistical forecasting.

GS 314 — Philosophy of Science — (3-0)3

This subject analyzes the methods and techniques of inductive and deductive science. Elementary logic is studied and applied to the necessary structure of scientific systems. The great concepts and generalizations which have marked the history of science are reviewed and analyzed, as well as the interrelation of science and general philosophy.

GS 321 or 322 — Industrial Marketing — (3-0)3

Marketing principles as they affect the engineer entering the manufacturing enterprise. Emphasis on industrial aspects of marketing including such factors as procurement (make or buy), pricing, and distribution.

GS 341 — Accounting I — (3-0)3

The significance of accounting, its underlying theories, and the organization and use of modern accounting records. The preparation of the balance sheet and profit and loss statement. Theory of debits and credits as applied to journalizing and usage of various ledgers and journals. Comparison of corporate, partnership, and proprietorship forms of organization from the accounting standpoint.

GS 342 — Accounting II — (3-0)3

[GS 341]

A continuation of GS 341 with emphasis on partnership and corporate accounting. Tax accounting; installment and branch

accounting; interpretation and analysis of formal financial statements; preparation of accounting reports. General study of cost accounting principles and applications.

GS 344 Cost Accounting (3-0)3
[GS 341]

Cost finding for manufactured goods. The necessity and principles of material control and accounting; direct labor accounting, overhead accounting, and distribution costing. Job order, process, and standard cost accounting systems are utilized.

GS 361-362 Advanced Technical German (3-0)(3-0)6
[GS 262 or equivalent]

GS 361 may be taken without continuing GS 362.

This subject is designed to expand the student's elementary understanding of the language, increase vocabulary, and develop reading aptitudes in special fields of interest selected by the student.

GS 371 or 372 American Civilization to 1865 (3-0)3

The beginnings of a national consciousness viewed from the aspects of the cultural, economic, and social evolution of the American people. The way of life of a growing democracy—its methods of livelihood, its art, its religious activities, its industries, its literature.

GS 401 or 402 Industrial Relations Seminar (2-0)2
[Permission of instructor]

This subject gives a small, selected group opportunities to meet with the instructor and occasional visitors in discussion of current problems in industrial relations. Case material and hypothetical problems in modern labor management provide the basis for group study.

GS 404 Government and Business (3-0)3

An examination of the direct controls imposed by federal, state, and local governments upon business activity. Emphasis is placed upon the economic interpretation of the various government statutes, and important court decisions affecting business are studied.

GS 411 or 412 Industrial Management: Principles and Problems (3-0)3

Backgrounds of modern industry, organization of the industrial enterprise, the operation of modern industry, and coordination of the productive processes. Among the topics covered are risks, forecasting, financing, product development, plant layout,

production controls, personnel management, time and motion studies, job evaluation, and wage and salary administration. The text material is supplemented with current readings and case material.

GS 421 **Industrial Procurement** **(3-0)3**

[GS 321 or 322]

Not offered in 1959-60

Purchasing procedure, quality control, inventory control, source selection, forward buying and speculation, and salvage operations as applied to the manufacturing enterprise.

GS 441 **International Trade Theory** **(3-0)3**

[GS 202]

Trade theory from Ricardo through modern concepts. International payments, national exchange and trade control, and policy determination.

GS 442 **Export Sales Management** **(3-0)3**

[GS 321 or 322]

World marketing from the viewpoint of the American producer. Management of foreign operations and location of production abroad.

GS 443 **Industrial Advertising** **(3-0)3**

[GS 321 or 322]

The principles of advertising and their application to the industrial field. The use of trade papers, direct mail, and other forms of advertising media.

GS 444 **Sales Management** **(3-0)3**

[GS 321 or 322]

Sales management in its broader aspects. Sales organization, management of a sales force, compensation of salesmen, and the selection, training, and supervision of salesmen. Market research, product packaging and development, and distribution policies are also considered.

GS 459 **International Relations** **(3-0)3**

The nature of the state system involving the state itself, nationalism, sovereignty, and national power; the various tools and instruments which states have available for use in the promotion of their national interest; and the controls present to restrain states and make possible international order.

GS 461 Personnel Management (3-0)3

A comprehensive study of modern labor management techniques in the recruiting, selection, training, and placement of members of the work force. Personnel administration agencies and procedures, with special attention to such matters as employee health and safety, welfare and recreation programs, wage and salary administration, training and education, and management relations with labor organizations.

GS 463 or 464 Business Law (3-0)3

The principles of commercial law including contracts, agency, sales, partnerships, corporation, negotiable instruments, bailments and carriers, insurance, personal property, real property, suretyship and guarantee, and bankruptcy.

GS 465 or 466 Management Problems Research (3-0)3

[Permission of instructor]

Normally restricted to seniors and graduate students.

Under faculty guidance, a student studies a topic in the field of finance, marketing, or production. The findings are presented in formal thesis form. These theses are retained by the Department for permanent reference.

GS 468 Investment Fundamentals (3-0)3

[GS 307]

The nature of different types of corporate securities from the viewpoint of the individual investor. Emphasis is placed upon the significance of various analytical techniques involved in appraising the intrinsic merits of industrial securities. Investment policy problems of portfolio construction are considered.

GS 470 Comparative Modern Governments (3-0)3

Twentieth-century political thought and the structure and functions of government agencies in democratic and totalitarian political systems. Emphasis is given to new concepts of government authority and responsibility and to changing patterns of international relations.

GS 472 American Foreign Policy, 1774 to the Present (3-0)3

The development of U. S. foreign policy from the beginnings of the Republic to the present. Particular attention is given to the influences of two world wars and their aftermaths upon American participation in global politics.

GS 473 The Modern American Novel (3-0)3

A consideration of outstanding American novelists from 1920 to the present. Selected works of Faulkner, Fitzgerald, Hemingway, Wolfe, and others are read and discussed.

GS 474 **Modern Drama** **(3-0)3**

An analysis of major forces in the theatre from the time of Ibsen to the present. Selected representative plays of American and European dramatists are read and discussed.

GS 475 **Contemporary English Literature** **(3-0)3**

A survey of the major English writers of this century with representative readings from novelists such as Hardy, Huxley, Conrad, Orwell, and Waugh; from such poets as Brooke, Owen, Eliot, Spender, Thomas, and Auden; from Maugham, Galsworthy, Shaw, and other dramatists; and from representative nonfiction prose writers—Russell, Toynbee, and Churchill. Supplementary readings in literary, political, and social backgrounds of the period are required.

LEATHER

LE 202 **Applied Leather Analysis** **(1-4)2**

[CH 102]

A subject designed to acquaint the student with the accepted methods of analysis of the American Leather Chemists Association and other supplementary procedures.

LE 301-302 **Leather Technology** **(3-6)(3-6)10**

Introduction to the technology of leather manufacture. The first semester is devoted to examining government regulations in imported hides and skins, studying the puchasing of hides and skins, and classifying various hide damages. This is followed by work on the handling of raw stock at the tannery, unhairing, bating, and hide classification. The second semester is concerned primarily with the study of vegetable tanning, chrome tanning, and various other types of tanning. In the work throughout the year the material covered in lectures is supplemented by laboratory studies on a small scale.

LE 303 **Leather Histology** **(2-4)4**

[CH 201-202]

A study of the structures of animal skin and of the changes which they undergo in the leather-making process. Because the basically extracellular nature of skin demands it, considerable time is devoted to the nature and function of the fundamental protein constituents.

LE 304 **Leather Microbiology** **(2-4)4**

[CH 202 or permission of instructor]

An introduction to the study of microbiology, with special emphasis placed upon the microorganisms which may be encountered on skins or in the tannery.

LE 401-402 **Leather Technology** **(3-6)(3-6)10**

[LE 302]

A continuation of the study of the technology of leather manufacture covering the various currying treatments applied to rough leather, such as fatliquoring, stuffing, dyeing and the various mechanical operations of setting, stretching, etc. It is intended to show how widely the physical properties of leather may be varied and controlled by the proper application and selection of these numerous operations and treatments.

LE 404 **Properties of Leather** **(2-3)3**

[EN 351 and LE 401]

A practical and theoretical study of the characteristics of leather in relation to the end use. Studies are made on measuring and classifying the effect of changes in manufacturing procedure, both chemical and physical. Leather, because it is a natural product, varies considerably within the same hide. Thus, the nature of this variation is very important and the study of any changes affecting it is, in turn, important.

LE 405 **Leather Seminar** **(1-0)1**

A seminar on recent advances in leather research. Written and oral reports are required, and time is devoted to techniques of proper presentation of these reports.

LE 406 **Leather Seminar** **(1-0)1**

A continuation of LE 405.

LE 411-412 **Leather Problems** **(1-6)(1-6)6**

[LE 302]

This subject is designed primarily to enable the student to put into practical application the various scientific principles of physics, chemistry, mathematics, economics, etc. on problems of an industrial nature. This may encompass anything from the design and layout of any of a number of special leather plants to the suggested solution of practical problems which arise in the operation of a modern leather business.

LE 501-502 **Tanning Mechanism** **(3-0)3**

A study of the principal tanning processes in the light of modern concepts of chemistry. A critical appraisal of the information documented in the literature in comparison with actual experience taken from the technological aspects of tanning.

LE 503-504 **Microbiological Studies of Leather** **(3-5)5**

The general principles and laboratory techniques of microbiology are considered. Special emphasis is placed upon the bacterial and mycological problems arising in the leather industry.

LE 505-506 **Graduate Seminar** **(1-0)1**

Round-table discussion among staff members and graduate students on certain phases of thesis work, published scientific reports, and recent progress in leather technology.

LE 507-508 **Graduate Thesis** **Credits to be arranged**

LE 509-510 **Microbiology of Skins** **(3-5)(3-5)10**

A study of microorganisms found in and on skins, their identification, classification, and enumeration. In addition consideration is given to the biochemical activities of these organisms and their importance in the handling of skin and the making of leather.

MATHEMATICS

MA 107 **Introduction to Mathematical Analysis** **(4-0)4**

This subject is intended to provide a firm foundation for the student's subsequent studies in the nature and the use of mathematical functions. Topics considered include functions and graphs, logarithmic and exponential functions, the differentiation and integration of simple functions together with applications involving related rates, differentials, maxima and minima, areas, volumes, lengths of curves, pressure, and work.

MA 108 **Calculus and Analytic Geometry** **(5-0)5**

[MA 107]

The conic sections; equations of motion; mean value theorem; the differentiation and integration of trigonometric, inverse trigonometric, logarithmic, and exponential functions; centroid and center of mass; the theorems of Pappus; moment of inertia; polar coor-

dinates; determinants; synthetic division; properties of roots of higher-degree functions; the translation and rotation of curves; hyperbolic and inverse hyperbolic functions; and further applications to chemistry and physics.

MA 205 Calculus and Analytic Geometry (4-0)4
[MA 108]

Integration by parts, integration by partial fractions, other integral forms, parametric equations, differentiation of vectors, tangential and normal vectors, elementary vector analysis, solid analytic geometry, partial differentiation, multiple integrals, infinite series, and complex functions.

MA 206 Differential Equations (3-0)3
[MA 205]

The solution of ordinary differential equations and of partial differential equations of the first order and first degree and of forms in certain other orders and other degrees that lend themselves readily to solution. Practical applications to chemistry and engineering.

MA 301-302 Advanced Calculus (3-0)(3-0)6
[MA 206]

A further study of differential equations. The Laplace transformation, numerical methods for solving differential equations, series solutions of differential equations, boundary value problems and orthogonal functions, vector analysis, partial differential equations arising in mathematical physics, and problems suitable for the use of a complex variable. Extensive applications.

MA 306 Theory of Equations (3-0)3
[MA 108]

Mathematical induction, complex numbers, integral and rational roots, solution by radicals, impossibility of certain geometrical constructions, number of real roots, isolation of a root, determinants, and approximate methods of solution.

MA 403-404 Modern Mathematical Methods (3-0)(3-0)6
[MA 302]

An introductory course in modern mathematical techniques. Set theory, sets and functions, cardinal numbers. Linear algebra, vector spaces, and matrix theory. Elements of probability theory, Markov chains and statistics.

MA 406 **Mathematical Statistics** **(3-0)3**

[EN 351, MA 205]

Measurements of dispersion, theoretical frequency distributions, tests of goodness of fit and independence, partial and multiple correlations; permutations, combinations, and probability; game theory.

MA 513 or 514 **Tensors and Matrices** **(3-0)3**

The algebra of vectors and matrices. Special matrices and quadratic forms. The tensor concept, covariant and contravariant tensors, the metric tensor and other associated tensors. Covariant differentiation, Riemannian and Euclidean spaces with applications to geometry.

MA 515 **Mathematics of Engineering Systems** **(3-0)3**

The solution of linear differential equations by classical methods and by modern methods, and the solution of nonlinear differential equations by various methods.

MA 533 or 534 **Matrix Theory** **(3-0)3**

Linear vector spaces. The algebra of vectors and matrices. Linear transformations, special matrices and quadratic forms. Characteristic roots and reduction to diagonal form. Applications to physics and quantum mechanics.

MA 537-538 **Group Theory** **(3-0)(3-0)6**

Elements of set theory. Mappings, isomorphisms, and cardinality. Semigroups and groups. The theory of finite groups. General representation theory. Applications of group theory to quantum mechanics.

MA 541 or 542 **Fourier Series and Boundary Values** **(3-0)3**

[MA 206]

The Fourier series as a tool of analysis. Dirichlet's Theorem. Orthogonal functions. Convergence tests. The Fourier integral. Cylindrical and spherical harmonics. Boundary value problems.

MA 545 or 546 **Partial Differential Equations** **(3-0)3**

The Cauchy problem. Classification of equations. Special emphasis on hyperbolic, elliptic, and parabolic differential equations. Existence and uniqueness theorems; dependence of solutions on boundary conditions.

MA 553 or 554 **Tensor Analysis** **(3-0)3**

The tensor concept. Covariant and contravariant tensors. The metric tensor, associated tensors, and covariant differentiation. Euclidean and Riemannian manifolds. Applications to geometry and analytical mechanics.

MA 573 or 574 **Functions of a Complex Variable** **(3-0)3**

Complex numbers, point sets, and elementary functions. An introduction to regular analytic functions. Classification of singularities. Conformal mapping and applications.

MA 591 or 592 **Graduate Thesis** **Credits to be arranged**

The graduate thesis covers an independent investigation undertaken by the student of a problem which is of interest to a member of the faculty and has the prior approval of the Department Head. The thesis must show ability and originality and must be a clear and systematic written presentation of the results.

PAPER

PA 301 **Pulp Technology** **(3-0)3**
[CH 211]

Lectures and problems concerning the technology of pulp manufacture by the ground-wood, sulfite, alkaline and semi-chemical processes. Bleaching methods are studied.

PA 302 **Paper Technology** **(3-0)3**
[CH 211]

Lectures and problems concerning the technology of paper manufacture. Material covered includes stock preparation, filling and loading, sizing, coloring, special additives, paper machine operation, and finishing.

PA 303 **Pulp Laboratory** **(2-6)4**
[CH 211]

This as well as subsequent laboratory work is designed with a research-type approach to develop the student's ability to plan and analyze the experimental work and to reach logical conclusions from the results. Studies are made of the principal wood, rag and wastepaper pulps. The work includes wood and pulp microscopy, bleaching, and evaluations of pulps for their papermaking value by physical and chemical testing methods. Detailed written and oral reports are required.

PA 304 **Paper Laboratory** **(2-6)4**

[CH 211]

Studies of the fundamental processing techniques used in paper manufacture. The work includes investigations of stock preparation, filling and loading, coloring, use of additives, and sheet formation. Detailed written and oral reports are required.

PA 403 **Converting Technology** **(3-0)3**

[PA 302 and 304]

Lectures and problems concerning the technology of paper and paperboard conversion by mechanical, coating, impregnating, laminating and printing processes.

PA 405 **Converting Laboratory** **(2-6)4**

[PA 403, usually taken concurrently]

Study of and practice in the use of the common techniques employed in the paper and paperboard industry. Emphasis is given to the colloidal and rheological properties of materials used. Detailed written and oral repors are required.

PA 408-409 **Summer Mill Inspection Trip** **No credit**

Two days before fall registration the members of the new junior and senior classes make an extended trip to visit pulp, paper, board and/or converting mills. Although no credit is given, attendance is required for graduation.

PA 411 **Wood Chemistry** **(3-0)3**

[CH 202, 332, 334; PA 301, 302]

The chemistry of cellulose, lignin, and other major constituents of wood as it applies to pulp and papermaking.

PA 414 **Paper Problems** **(2-6)4**

The senior is given an opportunity to work on a problem connected with some phase of the pulp, paperboard, or converting industry. Original application of accumulated knowledge of chemical and engineering principles is expected. Problems are selected by the student in collaboration with the staff and an advisory committee from the industry. One detailed formal report is required.

PA 501-502 **Graduate Thesis** **(1-9)(1-9)8**

Every graduate student is required to prove his ability to carry on independent research by presenting a thesis on an approved subject.

PA 503-504 **Plant Design** **(4-0)(4-0)8**

[CH 333, CH 442, PA 302]

Design of a paper, boardmaking, or converting process and plant. Included are the material and labor requirements, equipment selection (or design where commercial equipment is not available), the plant layout, and complete economic analysis. One detailed, formal written report including blueprints of equipment and plant layout is required. Principal reference texts: Vilbrandt, *Chemical Engineering Plant Design;* Schweyer, *Process Engineering Economics.*

PA 505-506 **Advanced Papermaking and Paper Converting** **(2-6)(2-6)8**

Nonfibrous raw materials used in the specialty papermaking and paper-converting fields with emphasis on recent developments and new uses. These materials are studied with regard to their chemical and physical properties, the technology of application, and processed sheet properties.

PA 507-508 **Graduate Seminar** **(1-0)(1-0)0**

Every graduate student is required to attend a weekly seminar with the staff. Student thesis progress, articles in recent literature, and unpublished recent developments in the field are discussed.

PHYSICS

PH 103 **Physics** **(4-1)4**

[MA 107 taken concurrently]

The principles of mechanics, including composition and resolution of vectors, statics, moments, rectilinear motion, Newton's second law, motion of a projectile, work and energy, impulse and momentum, circular motion, rotational kinematics and dynamics, elasticity, harmonic motion, hydrostatics, hydrodynamics, and viscosity.

PH 104 **Physics** **(4-1)4**

[MA 108 taken concurrently, PH 103]

Heat, sound, and the basic principles of electricity and magnetism, including the following topics: thermometry, quantity of heat, change of state, heat transfer, thermal properties of matter, the first and second laws of thermodynamics, wave motion, vibrating systems, acoustical phenomena, Coulomb's law, potential, d.c. circuits, the magnetic field, galvanometers, ammeters, voltmeters, watt-

meters, the d.c. motor, magnetic field of a current and of a moving charge, induced electromotive force, capacitance and inductance, and magnetic properties of matter.

PH 205 **Physics** **(3-2)4**

[MA 205 taken concurrently, PH 104]

Electricity and optics, including the following: transients in circuits containing inductance, capacitance, and resistance; thermoelectricity; ferromagnetism and ferroelectricity; alternating currents; electromagnetic waves; electronic phenomena; the nature and propagation of light; reflection and refraction at a single surface; lenses and lens aberrations; optical instruments; illumination; color; chromaticity diagrams; interference and diffraction; resolution; polarized light; and properties of crystals.

PH 206 **Physics** **(3-2)4**

[PH 205]

Modern physics, including the atomic nature of matter and electricity, variation of mass with velocity, isotopes, the nature of radiant energy, black bodies and the origin of the quantum theory, photoelectricity, spectra, Bohr's theory of the atom, X-ray spectra, waves associated with material particles, the spinning electron, Pauli's principle, magnetic moment of an atom, the periodic system and quantum numbers, molecular structure, radioactivity, elementary particles, scattering and absorption of particles and photons, transmutation, fission, reactors, fusion, cosmic rays, mesons, hyperons, and relativity.

PH 211 or 212 **Intermediate Mechanics** **(3-0)3**

[MA 205 taken concurrently, PH 104]

Motion under an inverse square force, attractive or repulsive. Damped and forced vibrations. Elements of related mathematical topics, including vector analysis. Dynamics of a rigid body. Gyroscopic motion.

PH 222 **Intermediate Thermodynamics** **(3-0)3**

[MA 206 taken concurrently, PH 104]

Kinetic theory of gases. First and second laws of thermodynamics. Standard cycles. Equilibrium between phases. Chemical equilibrium. Thermoelectric phenomena. Nonquantum theory of black-body radiation. Third law of thermodynamics.

PH 244 **Optical Instruments** **(1-2)2**

[PH 206 taken concurrently]

The basic laws of optics and their application to various optical instruments used in industry, such as the microscope, telescope, refractometer, and colorimeter. Considerable emphasis in the laboratory work is placed on the general use of the microscope.

PH 251 **Intermediate Electricity** **(3-3)4**

[MA 205 and PH 205 taken concurrently]

Electric field, potential, Gauss' law, dipoles, Poisson's and Laplace's equations, image problems, dielectric theory, energy, capacitance, force, electric current, d.c. circuits, steady magnetic fields, electromagnetic induction, magnetic properties of matter, L-C-R circuits, analysis of a.c. circuits, and Maxwell's equations.

PH 254 **Electronics** **(3-3)4**

[PH 251]

The characteristics of vacuum and gaseous electron tubes and semiconductors and the properties of circuits which include them in such basic functions as rectifying, amplifying, oscillating, and modulating. Positive and negative feedbacks; circuit response to wave forms; differentiating, integrating, clipping, and other circuits. The use of electronic instruments of importance to the physicist and mathematician in measurements on basic circuits.

PH 301 or 302 **Advanced General Physics** **Credits to be arranged**

[Permission of instructor]

Selected topics in mechanics, heat, sound, electricity, optics, and modern physics presented on an advanced level and emphasizing the interdependence of higher mathematics, classical physics, and practical concepts of engineering.

PH 311 or 312 **Physical Mechanics** **(3-0)3**

[PH 211]

Introduction to the calculus of variations, generalized coordinates, Hamilton's principle, theory of vibrating systems, normal coordinates, and elementary boundary value problems.

PH 323 or 324 **Statistical Mechanics** **(3-0)3**

[PH 222]

Introduction to the calculus of probabilities. Maxwell-Boltzmann statistics, Bose-Einstein statistics, Planck's theory of black-body radiation, and Fermi-Dirac statistics.

PH 343 or 344 **Atomic Physics** **(3-1)3**

[MA 206, PH 206]

The atomic models of Bohr and Sommerfeld. Quantum mechanics. One-electron, two-electron, multielectron systems. Doublet, triplet, and multiplet series. Zeeman effect. Paschen-Back effect. Stark effect. Correlation of theory with observation.

PH 351 or 352 **Electronic Circuits** **Gen. Eng. (3-2)4**
(Former PH 321 or 322) **Others (3-1)3**

[PH 205]

Characteristics of electron tubes and semiconductors, and their circuits for the basic functions of rectification, amplification, oscillation, and modulation. Fourier analysis, circuit analysis by the graphical technique for nonlinear characteristics and by the linear equivalent circuit, and the response of basic circuits to simple wave forms. Laboratory work for practice in the setting up and analyzing of fundamental circuits, emphasizing the principles and use of basic electronic instruments.

PH 353 or 354 **Electromagnetic Theory** **(3-0)3**

[MA 301 or 302 taken concurrently, PH 251]

Theory of electromagnetic fields. Polarization fields, solutions of Laplace's equation, magnetic potentials, Maxwell's equations and their application to guides and cavities. Fresnel's equations. The Hertzian oscillator.

PH 355 or 356 **Physical Electronics** **(3-3)4**

[MA 206, PH 206]

Motion of charged particles in electric and magnetic fields, and examples of electron optics in instruments; statistical theory of metals: behavior of electrons in solids; the phenomena of thermionic, photoelectric, and high field emission from metals; and boundary layer contact potential. Characteristics of thermionic cathodes. Diode and multielement vacuum tube characteristics and circuits. Noise; elements of radioastronomy. Kinetic theory of gases: fundamental processes in gases; electrical discharges in gases; phenomena of plasma and the effects of ionized regions on radiation; the operational characteristics of popular gas tubes.

PH 357 or 358 **Electrical Measurements** **(2-3)3**

[MA 206, PH 206]

Precision of measurements, zero frequency and low frequency measurements by both deflection and null methods, amplifiers and tube electrometers, oscillographs, measurements at high frequencies, magnetic measurements, electrical measurements in mechanics, heat, acoustics, optics, and nuclear science.

PH 361 or 362 **Intermediate Nuclear Physics** **(3-0)3**

[MA 206, PH 206]

The elements of wave mechanics. The deuteron, n-p scattering theory. Alpha decay theory and radioactivity. Gamma and beta radiation. Range-energy relations. Particle detectors. Neutron diffraction. Nuclear structure, nuclear reactions.

PH 411-412 **Quantum Mechanics** **(3-0)(3-0)6**

[MA 403-404 taken concurrently, PH 311 or 312]

Historical introduction. The uncertainty principle, Schrodinger's equation, and the wave mechanics of a particle. The general theory of quantum mechanics, matrix methods, and perturbation theory. Relativistic wave equations with emphasis on the Dirac theory of the electron.

PH 421 **Physical Thermodynamics** **(3-0)3**

[MA 302, PH 222]

Not offered in 1959-60

PH 431 or 432 **Theory of Vibrations and Sound** **(3-0)3**

[MA 301, PH 312]

Free, damped, and forced oscillations; forcing by pulses; coupled oscillations; the flexible string; end conditions; perturbations; the vibration of bars, membranes, and plates; sound waves; acoustic impedance; the radiation and scattering of sound; normal modes; and reverberation. Applications are stressed.

PH 461-462 **Nuclear Physics** **(3-0)(3-0)6**

[PH 361 or 362; MA 403 and PH 411-412 taken concurrently]

The general properties of the nucleus. The nuclear radius, nuclear moments and the systematics of stable nuclei. Nuclear forces, nuclear models. Radioactive decay, nuclear reactions, and cross-sections. The interaction of nuclear radiations with matter.

PH 471-472 **Solid State Physics** **(3-0)(3-0)6**

[PH 411-412 taken concurrently]

Crystal structure and X-ray and neutron diffraction. Free electron model. Band theory of solids. Quantum mechanical considerations. Lattice energy, lattice vibrations, infrared absorption. Lattice defects. Thermal properties of solids. Dielectric and magnetic properties. Mechanical properties. Semiconductor crystals.

PH 493-494 **Advanced Laboratory** **(0-4)(0-4)2**

A laboratory course which may be taken to accompany certain advanced physics courses or which may serve as a vehicle for undergraduate experimental research in a selected field of physics. Open to students whose qualifications are satisfactory.

PH 501 or 502 **The Physics of Color Measurement** **Credits to be arranged**

[MA 206, PH 206]

The philosophy and practice of modern colorimetry. Colorimeters, their uses and limitations, spectrophotometers, tristimulus values, dominant wavelength and purity, the "standard observer"

concept, the Munsell system, the Ostwald system, color tolerances, gloss and body color, illuminants, and industrial applications.

Laboratory instruments available consist of brightness testers, monochromatic and trichromatic colorimeters, recording and visual spectrophotometers.

PH 511 — Classical Mechanics — (3-0)3

Selected topics in analytical dynamics, with emphasis on those most applicable to quantum mechanics and field theory.

PH 514 — Statistical Mechanics — (3-0)3

[MA 302, PH 324]

Relations between wave mechanics and quantum statistics. Applications of statistical mechanics to the theories of gases, liquids, and solids.

PH 515-516 — Advanced Quantum Mechanics — (3-0)(3-0)6

Operators and observables. The quantum theory of measurement. Spin and relativistic wave equations. The Dirac theory of the electron, Feynman diagrams, and selected topics in scattering.

PH 518 — Relativistic Particle Mechanics — (3-0)3

Not offered in 1959-60

PH 523 — Low Temperature Physics — (3-3)4

[MA 302, PH 222]

The production of low temperatures in various ranges, thermometric problems, the magnetic temperature scale, properties of paramagnetic salts, behavior of specific heats, nuclear polarization and alignment, solid and liquid helium, superfluids, second sound, superconductivity, thermal conductivity at low temperatures, the third law of thermodynamics.

PH 531 — Acoustics — (3-3)4

Not offered in 1959-60

PH 534 — Crystal Vibrations — (3-3)4

Not offered in 1959-60

PH 543 or 544 — Spectrographic Methods — (2-3)3

[PH 206]

The theory and application of the spectrograph for the qualitative and quantitative analysis of materials. The Bohr theory, quantum mechanics, atomic models, and the theoretical prediction of line and band spectra. Special attention is placed in the laboratory on the analysis of elements in paper, leather, and textile samples, and individual problems are assigned to the students.

PH 545 or 546 X-Ray Diffraction (2-3)3

Theory of X-ray production. Absorption. Scattering by electrons and atoms. Crystallographic notation. Laue equations. Determination of crystal structure. For those whose background interests involve fibers, some opportunity for investigation of these is offered in the laboratory work.

PH 547 or 548 Electron Microscopy and Electron Diffraction (2-3)3

[PH 206, PH 251]

Analogies with optics; electrostatic and magnetic lenses; electron trajectories; solutions of the Laplace and paraxial ray equations; vacuum techniques; the scattering of electrons; electron diffraction: wave properties of the electron, diffraction patterns, crystallographic terminology, reciprocal lattice; replicative, photographic, and other laboratory techniques in electron microscopy and diffraction.

PH 553 Piezoelectricity and Ferroelectricity (3-3)4

Crystallographic bases of piezoelectricity, crystal elasticity, rotated axes, modes of vibration; behavior and interactions of the elastic, dielectric, and piezoelectric coefficients; ferroelectric crystals, domain structure, transitions between phases, free and clamped states; applications of piezoelectric and ferroelectric crystals.

PH 562 Advanced Nuclear Physics (3-0)3

A theoretical course treating the general aspects of nuclear reactions. Alpha and beta decay. Nuclear models and recent advances in nuclear physics.

PH 563 Microwave Spectroscopy (3-3)4

Not offered in 1959-60

PH 565 Nuclear Resonance Methods (3-3)4

Not offered in 1959-60

PH 568 Neutron Diffraction Analysis (3-0)3

The diffraction of neutrons in crystals and its applications in the determination of lattice structures and magnetic moments.

PH 575-576 Problems in Solid State Physics (3-0)(3-3)7

Quantum mechanics and specific heats, lattice energy, elastic coefficients, applications of statistical mechanics, ferroelectric crystals, diamagnetism and paramagnetism, Brillouin zones, Hume-Rothery rules, order-disorder transformations, semiconductors, ferromagnetism and antiferromagnetism, ferrimagnetism, magnetic re-

laxation and resonance, superconductivity, lattice vacancies, diffusion, color centers, excitons, dislocations, thermal and electrical conductivity at low temperatures.

PH 581 Information Theory (3-0)3

Not offered in 1959-60

PH 583 or 584 Relativity Theory (3-0)3

Invariance of physical laws. Tensor formulation of the special theory of relativity and applications. The general theory of relativity.

PH 585-586 Classical Field Theory (3-0)(3-0)6

The theory of electromagnetic fields. Elements of special relativity. The covariance formulation of Maxwell's equations. Applications such as the classical treatment of the field of moving charges, radiation, scattering, and physical optics. Introduction to gravitational fields.

PH 588 Computers (3-0)3

[MA 302, PH 254]

The principles of analog and digital computers as a basis for assessing and planning their use in scientific work. Logical design, instrumentation, programming, and mathematical analysis and techniques. A survey of the well-known commercial analog and digital computers, and a visit to a local computing center during which a course-programmed problem may be seen.

PH 590 Field Theory (3-0)3

Not offered in 1959-60

PH 591 or 592 Graduate Thesis Credits to be arranged

The graduate thesis covers an independent investigation undertaken by the student of a problem which is of interest to a member of the faculty and has the prior approval of the Department Head. The thesis must show ability and originality and must be a clear and systematic written presentation of the results.

PLASTICS

PL 201-202 **Plastics Technology I** **(2-0)(2-0)4**

A descriptive subject to acquaint the student with plastics as a class of materials. The history, definitions, classes, properties, and applications of plastics.

PL 301-302 **Plastics Technology II** **(2-2)(2-2)6**

[PL 201-202]

Raw materials and manufacturing processes. Methods of processing plastics materials, including compounding, molding, casting, extruding, laminating, fabricating, and finishing. Evaluation and development of typical plastics problems. Laboratory instruction in the processing and fabrication of plastics materials.

PL 401-402 **Plastics Technology III** **(2-3)(2-3)6**

[PL 301-302]

Application of plastics as engineering materials. Product, equipment, and mold design. Correlation of composition, processing, and fabrication with product design and applications. Continuation of laboratory instruction in processing, molding, and fabrication.

PL 403-404 **Properties of Polymers** **(2-3)(2-3)6**

[Open to seniors only]

Important engineering properties of plastics materials; the theory of testing; examination of testing techniques, equipment, and standard ASTM methods for evaluating mechanical, thermal, electrical, and optical properties.

PL 411-412 **Plastics Seminar** **(1-0)(1-0)2**

[Open to seniors only]

Informal discussions, based on literature study conducted by the individual, of topics in, or related to, plastics engineering.

TEXTILES

TE 200 **Textile Fibers** **(4-0)3**

[CH 203]

Similar to TE 201 and TE 202, but less detailed. Primary emphasis is upon fiber properties.

TE 201N **Technology of Fibers** **(3-1)3**

A study of the important textile fibers, both natural and man-made, from the viewpoints of fiber classifications, origins of natural fibers and production of man-made fibers, geographic distribution, grading, marketing practices, and consumption.

TE 202N **Mechanical and Chemical Properties of Fibers** **(3-0)3**

[CH 203, TE 201N]

Classification systems of the important textile fibers in terms of their basic properties. Fundamental mechanical and chemical properties are taken up in detail to provide a basis for understanding the relationship of fiber properties of processing and utilization problems.

TE 210 **Fundamentals of Yarns** **(2-1)2**

[EN 205, TE 202N]

Consideration of the theory of making a yarn from staple fibers. The basic processing steps of opening, cleaning, carding, combing, drafting, and spinning are considered from the viewpoint of the mechanical principles involved independently of the particular fiber machinery system employed.

TE 311N **Woolen System Yarns** **(3-3)3**

[TE 210]

A study of the processing of textile fibers utilizing the woolen yarns machinery system, including the reclamation of fibers for re-use in the manufacture of yarns.

TE 313-314 **Worsted System Yarns** **(3-3)(3-3)6**

[TE 210]

A study of the processing of textile fibers using worsted yarns system machinery. Emphasis is placed upon fundamental aspects of the subject and the integration of this phase with TE 311N and TE 315-316.

TE 315-316 **Cotton System Yarns** **(4-4)(3-3)7**

[TE 210]

Similar in scope and emphasis to TE 313-314 except that the cotton yarns system machinery is employed.

TE 318 **Filament System Yarns** **(1-1)1**

[TE 210]

Concerned with the textile steps in processing the various filament yarns, as delivered by the chemical fiber producers, for use by the weaving and knitting elements of the textile industry.

TE 319N **Yarns: Cotton and Filament Systems** **(3-3)3**

[TE 210]

Similar to TE 315-316 and TE 318, but less detailed. Laboratory work consists of demonstrations only.

TE 320 **Yarns: Woolen and Worsted Systems** **(3-3)3**

[TE 210]

Similar to TE 311 and TE 313-314, but less detailed. Laboratory work consists of demonstrations only.

TE 321 **Elements of Textiles: Yarns** **(2-3)3**

The basic aspects of fiber properties, fiber preparation, and yarn manufacture by the common machinery systems.

TE 330 **Mechanics of Fabric Design I** **(4-4)4**

[TE 210]

A study of the fundamental theory and practice relating to the analysis and design of woven structures regardless of the fibers and/or yarns involved. The subject is introduced by presenting the various yarn numbering and classification systems as an integrated whole.

TE 332 **Fundamentals of Fabrics** **(4-4)4**

[TE 319N]

The analysis and design of woven fabrics regardless of the fibers and/or yarns involved. Lectures and laboratory demonstrations dealing with the machines and methods for the production of woven fabrics regardless of the fibers and/or yarns employed.

TE 334 **Elements of Textiles: Fabrics** **(2-3)3**

The basic aspects of the production of fabrics by weaving and knitting using common machinery systems.

TE 352N **Principles of Textile Operations II** **(3-3)4**

[TE 381]

Designed to cover the processing of fabrics from the loom to the finished state, regardless of construction or fiber content, and including the major steps of purification, coloring, and finishing. The major emphasis is on the mechanical engineering aspects of the processes, with the necessary chemical aspects required to supplement this approach.

TE 381 **Principles of Textile Operations I** **(4-4)4**

The elements of fiber preparation, yarn manufacture by all the common systems, weaving, and knitting are presented in an operational units manner, regardless of the fiber involved. Laboratory time consists of demonstrations only.

TE 410 **Cotton System Waste Processing** **(2-2)2**

[Permission of instructor]

A study of the methods and machinery employed in processing cotton wastes and/or new cotton on waste machinery. Individual student papers on an assigned topic are presented in class.

TE 411N or 412N **Product Quality: Cotton System Yarns** **(2-2)2**

[Permission of instructor]

Devoted to a study and analysis of product defects in the manufacture of yarns on cotton system machinery. Procedures necessary to avoid the defects are studied, and the diagnostic ability of the student to recognize and remedy defects is developed.

TE 413N or 414N **Multifiber Processing: Cotton System Yarns** **(2-2)2**

[Permission of instructor]

The blending and processing of various fibers utilizing cotton system machinery, with emphasis upon fiber properties and yarn characteristics.

TE 415N-416 **Technology of Cotton System Yarns** **(3-3)(3-3)6**

[Permission of instructor]

Restricted to graduate students with a mechanical engineering degree and may be taken to satisfy the undergraduate cotton system yarns requirement. While the scope is similar to TE 315-316, advantage is taken of the mechanical engineering background of the student.

TE 417N-418 Problems in the Technology of Yarns — **Credits to be arranged**

[Permission of instructor]

Restricted to qualified students in their senior year. Primarily a laboratory study of desirable spun-yarn properties and the influence of controlled process variables on these properties. Cotton, woolen, or worsted systems machinery may be employed. Emphasis is placed upon actual processing operations to achieve the desired end, the evaluation of the material for conformance to the desired objectives, and the interpretation of results. A final paper is required of each student.

TE 430N Identification and Classification of Fabrics — **(2-0)1**

[Permission of instructor]

Designed to impart knowledge relative to the important fabric types in use in wearing apparel, home furnishings, and industry. An analytical discussion approach is used so that not only may the fabrics be identified but also the significance of the fabric geometry and properties may be grasped.

TE 431N Mechanics of Fabric Design II — **(4-4)4**

[TE 330]

A continuation of TE 330.

TE 433-434N Technology of Woven Fabrics I and II — **(3-3)(3-3)6**

[TE 330, TE 431N concurrently]

Designed to familiarize students with the basic machines and techniques for the production of woven fabrics regardless of the fibers and/or yarns employed, from the preparation of yarns for introduction into a loom to the various loom actions and modifications available for the production of a variety of fabrics. Primary emphasis is upon the mechanical principles employed. This subject is closely integrated with TE 330 and TE 431N.

TE 436 Technology of Knitted Fabrics — **(3-3)3**

[TE 330]

Similar in concept and scope to TE 433-434N except that it is devoted to knitted fabrics. A broad survey of the important types of knitting. Considerable stress is placed on the various stitches and the characteristics of fabrics from each. Starting with flat machines, the work advances through small ribbers, automatic hosiery machines, full-fashioned hosiery machines, underwear machines, and warp knitters. The production, design, and analysis of knit fabrics and the classifications and routines for manufacture of hosiery and underwear are included.

TE 438 **Color Theory** **(1-1)1**

[TE 330 and 431N]

The study of color from a subjective viewpoint utilizing the Munsell Color System, with primary stress placed upon the relation of color to fabric design and structure.

TE 439N or 440N **Fundamentals of Jacquard Fabrics** **(1-1)1**

[Permission of instructor]

Sketching of original designs as applied to particular Jacquard fabrics, transfer of design to cross-section design paper, choice of weave structure for both the background and foreground, cutting and lacing of cards, and weaving of sample lengths of fabric.

TE 441 or 442 **Complex Woven Structures** **(2-1)2**

A study of Leavers lace design and production theory, production machinery, and manufacture. The same aspects of Schiffli embroidery are covered, as well as the fundamentals pertaining to chenille, Wilton, Brussels, tapestry, velvet, and Axminster carpets.

TE 443 or 444N **Problems in the Technology of Knitted Fabrics** **(3-3)3**

[Permission of instructor]

Basically an advanced subject for students interested in the manufacture of knitted fabrics. The student is encouraged to select a particular field from the various sections of the knitting industry and to concentrate on its problems.

TE 445 or 446 **Technology of Woven Fabrics III** **(2-2)2**

[Permission of instructor]

Additional work concerning the manufacture of woven fabrics. The Crompton & Knowles looms, including the overhead multiplier, filling mixer, and tricolor automatic loom, as well as the dobby looms including leno and terry attachments, the Jacquard heads, harness mounting problems, and carpet manufacture.

TE 447 or 448 **Color Theory** **(2-2)2**

[Permission of instructor]

Similar in concept to TE 438, but with additional time for the exploration in greater depth of the relation of color to fabric design and structure.

TE 449N **Weaving Laboratory** **(0-3)1**

[Permission of instructor]

Designed to provide additional time for the student in the weaving laboratory so that greater familiarization with the operation of various loom mechanisms may be acquired.

TE 451-452 **Technology of Finishing I** **(2-1)(0-2)3**

[CH 302, EN 311 or 403, TE 330 or 332]

Lectures and laboratory workshops in the major engineering and chemical considerations necessary to finish fabrics of wool and wool blends. The engineering aspects are stressed.

TE 453-454 **Technology of Finishing II** **(2-1)(0-2)3**

[CH 302, EN 311 or 403, TE 330 or 332]

Similar in concept and scope to TE 451-452 except that it is devoted to finishing fabrics made of cotton and man-made fibers processed on cotton system machinery.

TE 455-456 **Chemical Technology of Finishing I** **(2-1)(1-2)4**

[CH 202, 356, 364; TE 334]

The major aspects in the conversion of fabrics of wool or wool blends for utility, serviceability, or appearance. Stress is placed on the chemical phases but including such engineering aspects as are necessary to supplement and process to completion.

TE 457-458 **Chemical Technology of Finishing II** **(2-1)(1-2)4**

[CH 202, 356, 364; TE 334]

Similar in concept and scope to TE 455-456 except that it is devoted to finishing fabrics made of cotton and man-made fibers processed on cotton system machinery.

TE 471 **Testing of Textiles I** **(2-3)3**

Devoted to the basic mechanical tools and techniques and their utilization by the textile industry for research, development, product control, and end use evaluation. Moisture equilibrium and rates of change relations; basic fiber, yarn, and fabric dimensions; spatial relations and fluid flow instrumentation; an introduction to the determination and evaluation of the stress-strain-time properties of viscoelastic fibrous structures; and wear or abrasion of textile structures are among the topics considered.

TE 472 **Testing of Textiles II** **(2-3)3**

A consideration of basic chemical and optical tools and techniques available to the textile industry for research, development, product control, and end use evaluation. Quantitative and qualitative determination of fiber content, organic and inorganic nonfibrous constituents, evaluation of colorfastness properties, application of the physics of color measurement to dyed textiles, an introduction to microscope optics, and the utilization of microscopy in textile work are among the topics considered.

TE 481 **History of Costume and Adaptations** **(1-2)2**

[Permission of instructor]

A general coverage of typical costume through the ages from early Egyptian times to the present. The student is expected to make many modern adaptations inspired by period costumes.

TE 482 **Application of Scientific Methods to Textile Processes** **(3-0)3**

[EN 305 or 403; EN 316 and 407; MA 206]

A cross-discipline course which exercises the student in the application of his knowledge of science and engineering to problems of textile processing. In problem-solving sessions, an effort is made to simulate the resources and on-the-job environment of a practicing textile engineer.

TE 483-484 **Engineering Design of Textile Structures** **(3-0)(3-0)6**

[Permission of instructor]

This subject correlates engineering properties of textile materials, engineering principles, and textile processing in the design of textile structures with desired properties. The geometry of yarns and fabrics; design of textile structures for certain functional uses; prediction of dimensional changes which occur during use; stresses, strains, and energy changes which the end use imposes; analyses of load-elongation diagrams of textile structural material.

TE 501N-502N **Structure and Properties of Fibers** **(3-0)(3-0)6**

[Permission of instructor]

The molecular structure and arrangement of molecules in fibers are considered with respect to giving a foundation to the understanding of the physical and mechanical properties and behavior of these textile raw materials. These properties are examined from a fundamental viewpoint so that a sound approach to the technological utilization of fibers in textiles can be established. Such aspects as polymer structure, order, intermolecular forces and flexibility, as they relate to stress-strain characteristics, viscoelastic behavior, etc., are discussed as well as the effects of environmental conditions on these factors. An introduction is made to the interrelation between fiber properties and yarn and fabric geometry in determining the behavior of textiles.

TE 503N or 504N **Technology of Cotton Fibers** **(2-2)3**

[Permission of instructor]

Effects of various chemical, mechanical, and growth modifications of cotton on the chemical, physical, and processing properties of the cotton fiber. Problems are assigned for laboratory evaluation, and a paper for class delivery is required of each student.

TE 511N or 512N Plant Organizations: Cotton System Yarns (2-2)3

[Permission of instructor]

Designed to correlate the various aspects of yarn production using cotton system machinery. Emphasis is placed upon the need for proper balance among the machinery elements for the production of specific yarn types. Consideration of machinery layouts for efficient and economic operation of the total yarn establishment, with stress on the various calculations involved. Considerable use is made of the case history technique of presentation.

TE 515 or 516N Plant Organization: Woolen and Worsted System Yarns (2-2)3

[Permission of instructor]

Similar in concept and scope to TE 511N or 512N except devoted to the utilization of woolen and worsted systems machinery.

TE 531 or 532 Plant Organization: Fabric Production (2-2)3

[Permission of instructor]

Similar in concept and scope to TE 511N or 512N and TE 515 or 516N except that the subject pertains to the production of woven fabrics. Plant layout, production, and work loads for various basic woven fabric constructions are considered.

TE 533 or 534 Kinematics of Looms (2-2)3

[Permission of instructor]

Concerned with a study of loom motions, with emphasis upon instrumentation applications for the securing of pertinent information.

TE 571 or 572 Textile Microscopy (2-3)3

[Permission of instructor]

The principles involved in the use of the microscope for the qualitative and quantitative estimation of the morphological, physical, and chemical properties of textile materials.

TE 573 or 574 Mechanical Testing of Textiles (2-3)3

[Permission of instructor]

Thickness and compressional measurements, stress-strain-time phenomena of viscoelastic textile materials, Vibroscope theory and techniques, yarn uniformity, thermal determination, and friction evaluation are among the major topics covered. Emphasis is placed on current literature search assignments and the preparation of a student paper on a selected topic within the scope of the subject.

TE 581 or 582 Textile Plants Organization (2-2)3

[Permission of instructor]

A study of the numerous factors at the management level leading to the establishment of a textile plant. Location finding, labor supply, materials supply, transportation, community relations, and machinery balance are considered for various types of textile processing plants. The case history technique is used to advantage in this subject.

TE 591N Methods of Research (2-0)1

Required of all graduate students in Textile Engineering during their thesis year. A seminar to familiarize the student with the philosophy of research.

TE 592 Thesis Seminar (2-0)1

Required of all graduate students in Textile Engineering during their thesis year. Devoted to problems in the preparation and presentation of research work, with illustrative material drawn from thesis work in process.

TE 593-594 Graduate Thesis Credits to be arranged

Each graduate student in Textile Engineering is required to submit a thesis which shows ability and originality in the solution and presentation of a research project.

Other subjects pertaining to textiles are listed under Chemistry and Engineering. They are:

CH 302	Introduction to Textile Chemistry	(1-3)2
CH 311	Advanced Quantitative Analysis for Textile Chemists	(2-4)3
CH 355	Chemistry and Physics of Fibers	(3-3)4
CH 356	Chemistry of Fiber Purification	(2-3)3
CH 364	Textile Colloid Chemistry	(4-0)4
CH 401	Introduction to Textile Chemistry	(1-3)2
CH 408	Advanced Studies in Chemistry	Credits to be arranged
CH 422	Chemical Textile Testing	(2-3)3
CH 453	Theory of Dyeing	(3-4)4
CH 454	Industrial Dyeing and Printing	(2-8)4
CH 461	Microbiology	(1-3)2
CH 491	Textile Chemistry Literature Seminar	(2-0)2
CH 501	Color Measurement	(1-3)2
CH 505	Physical Chemistry of Dyeing	(2-3)3
CH 512	The Physical Chemistry of Surface-active Agents	(2-0)2

CH 551 or 552	Textile Testing Problems	(1-3)2
CH 553-554	Evaluation of Finishing Agents	Credits to be arranged
CH 555-556	Textile Chemistry Seminar	(2-0) (2-0)4
CH 559	Instrumental Methods in Textile Research	(1-2)2
CH 561-562	Polymer-Chemical Principles in the Technology of Organic Construction Materials	(3-0) (3-0)6
CH 563-564	Special Topics in the Chemistry and Technology of Manufactured Fibers	(2-0) (2-0)4
EN 429-430	Engineering Design of Textile Structures	(3-0) (3-0)6
EN 492	Application of Scientific Methods to Textile Processes	(3-0)3

The Graduate School

By act of the General Court of 1935, authority was given to the Lowell Technological Institute to confer degrees of Master of Science in the fields of Textile Chemistry, Textile Engineering, and Textile Technology upon graduate students who satisfactorily complete an approved program. More recently, authority has been extended to include graduate programs leading to the Master of Science degree in Paper Engineering, Electronic Engineering, Leather Engineering, Chemistry, and Physics and Mathematics. The latest addition to the Graduate School is a program in Chemistry leading to the Doctor of Philosophy degree. An option in this program allows for specialization in Textile Chemistry.

The graduate programs of study offered by the Institute provide for advanced specialized training required by technologists who contribute to industrial progress and human welfare through the application of scientific and engineering principles to existing industrial and human problems. The courses of study allow the graduate of the Institute, or of other colleges, who has specialized in either textiles, paper, leather, electronics, or chemistry to broaden his knowledge and skills in one of these areas and to develop a sound research approach to problems in the basic sciences, the engineering and development of new products, and industrial production. For those interested in teaching in these fields, the advanced classroom and seminar work, the research experience, and the opportunity to work with recognized leading teachers in the field are important.

ADMISSION TO THE GRADUATE SCHOOL

General Admission

To be eligible for admission to the Graduate School, an applicant must have received a bachelor's degree in an acceptable four-year course in which he has maintained a uniformly high scholastic rating. Both the quality and quantity of previous training will be considered. Selection of those applicants admitted will be based as far as possible on their ability to pursue graduate work of high quality.

Special Student Status

An applicant who meets the general admission requirements, but who wishes to concentrate on certain subjects in specialized techniques, or in some cases on special research programs, may request to be considered for Special Student status. This work does not lead to a degree.

Acceptance as a special student is contingent upon the consent of the instructor in charge of each subject to which admission is desired.

Provisional Status

An applicant for admission who is unable to meet all the requirements for general admission may be accepted provisionally, if he satisfies the department in which he wishes to enroll that he is probably able to pursue graduate studies successfully.

The status of such a student will be changed to that of a graduate student upon demonstration of his ability to pursue graduate studies successfully as measured by the completion of his first semester's work with an average rating of at least B (2.5 or 80%).

Application Procedure

Those wishing to carry on graduate studies at this Institute should file application with the Director of the Graduate School. Applications may be obtained from the Office of the Graduate School.

Applications for admission should be complete and accurate and must be received not later than the first of June preceding the fall term in which the applicant wishes to enroll. Applications must be supported by letters from at least two persons qualified to judge the ability of the applicant to carry on graduate work and research. The letters should be sent directly from these persons to the Graduate School.

Transcripts of all undergraduate records (and graduate, if any) must be sent directly to the Office of the Graduate School by the institutions which the applicant has previously attended. All transcripts must be official, with appropriate seals and signatures. Records, descriptions of subjects, and letters must be in English. Each subject must be described in terms of content, scope, number of hours per week, and number of weeks duration. Lecture and laboratory time should be properly distinguished. If a catalogue giving such descriptions in English is available, the subjects taken may be clearly marked in a copy sent to the Graduate School.

A reading and speaking knowledge of English is necessary for an applicant to be considered for acceptance. Most of the subjects are presented in lecture form, making it difficult for those who do not have a reasonably fluent command of the English language.

Except in unusual circumstances, applications will be acted upon and the applicant notified of the decision by July 1. Foreign applicants are urged to make application as early as possible so as to leave enough time for visa and other arrangements to be made.

GRADUATE COURSES OFFERED

Graduate programs leading to the Master of Science degree are offered in the fields of Chemistry, Electronic Engineering, Leather Engineering, Paper Engineering, Physics and Mathematics, Textile Chemistry, and Textile Engineering. A program leading to the Doctor of Philosophy degree in Chemistry with options in organic, physical, or textile chemistry is also available to qualified applicants.

Because of the varied objectives of the graduate student, the course of study is arrived at through consultation with the student's graduate adviser.

Subjects numbered 500 and above are offered for graduate credit. A limited number of undergraduate subjects are available for graduate credit. The choice of these undergraduate subjects with graduate credit is subject to the approval of the Department Head.

Each program will include an orginal thesis.

EXPENSES

Tuition, fees, and other expenses for graduate students are for the most part the same as given on page 34 for undergraduates. In addition, however, every graduate student is required to bear the cost of binding two copies of his thesis for the Institute's files. The doctoral candidate must also pay to have his thesis microfilmed. Students will not be permitted to register for thesis work until these fees have been paid at the library.

MASTER OF SCIENCE DEGREE PROGRAMS

Chemistry

This program has been developed to provide opportunity for advanced study and research training in chemistry. Chemistry subjects include both general and specialized fields of study. Provision is also made for the student to elect certain alvanced courses in related fields of mathematics, physics, and engineering.

Subject Requirements—Of the 20 credit minimum, exclusive of thesis and seminar required in listed courses (see Requirements for Graduation at the end of this section), a minimum of 15 credits must be taken in chemistry. Of these not more than 12 credits may be taken in approved undergraduate courses designated below by an asterisk, and normally credit will not be allowed in such a course taken in the major field of specialization, e.g., organic, physical, inorganic. Recommended courses include: *CH 403-404, *CH 423-424, *CH 431-432, *CH 443-444, CH 513-514, CH 521-522, CH 523-524, CH 525-526, CH 527, CH 528, CH 529, CH 531-532, CH 533, CH 534, CH 535-536, CH 538, CH 561-562. Each graduate program must include courses in organic chemistry, inorganic chemistry, and physical chemistry. All students must take Chemistry Seminar (CH 507-508). The remaining credits (five or more) may be taken in chemistry or in a related field such as physics, mathematics, or engineering. All subjects must be approved by the student's advisory committee.

Language Requirements—For the degree of Master of Science in Chemistry, the student must demonstrate his ability to read technical German.

Advisory Committee—The development of the student's program of study shall be the responsibility of an advisory committee consisting of three members from the faculty of the Division of Chemistry. This committee shall be appointed by the Director of the Graduate School upon the recommendation of the Division Chairman and shall include the thesis supervisor.

Thesis Examination—Each candidate for a Master of Science degree in Chemistry, upon completion of his thesis, shall present himself for an oral examination in the field of his thesis to an examination committee appointed by the Director of the Graduate School and consisting of his advisory committee and any additional faculty members considered desirable by the Director. While only members of the examination committee and the Director of the Graduate School may conduct the examination, all faculty members may attend. The examination shall be held after the thesis has

been accepted and within a period of two weeks prior to the close of the final semester. Application to take the examination must be filed by the student with the Director of the Graduate School at least one month prior to the close of the last semester. Each student has the right to one re-examination within a period of one year.

Electronic Engineering

The graduate program in Electronic Engineering is to be continued in 1959-1960 on a limited basis. The program is restricted to:

(a) graduates of the Lowell Technological Institute with a B.S. degree in Electronic Engineering, and

(b) qualified employees of neighboring industrial organizations which are participating in this graduate program.

Leather Engineering

A graduate program in Leather Engineering is offered for students who wish to work extensively in the field of leather technology. In general, only students possessing the B.S. degree in the chemical sciences or in leather engineering will be acceptable as candidates for the degree of Master of Science. In all cases, an examination of the undergraduate record of each candidate will be required before final acceptance. This is particularly necessary in cases where minor specializations in the fields of chemistry or mathematics have not been satisfied; a program based on fulfilling these requirements will then have to be completed with the general requirements for the advanced degree. In the case of students who have not had any leather technology, histology, or bacteriology, a certain portion of the graduate work will of necessity be required in these areas.

The following graduate subjects are offered in the department:

LE 501-502	Tanning Mechanism	(3-0)3
LE 503-504	Microbiological Studies of Leather	(3-5)5
LE 505-506	Graduate Seminar	(1-0)1
LE 507-508	Graduate Thesis and Oral Defense	10
LE 509-510	Microbiology of Skins	(3-5)5

It is suggested that approximately 50% of the graduate program should be chosen from the above subjects with the aid of the Department Head. The remainder should be chosen in fields related to leather technology. Suggested subjects in this area would be:

CH 503	Interpretation of Data	(2-0)2
CH 512	Physical Chemistry of Surface-active Agents	(2-0)2
GS 261-262	Technical German (but not for graduate credit)	

Paper Engineering

The graduate program in Paper Engineering is for the purpose of giving advanced work in papermaking, paper-converting or allied fields.

The Paper Engineering Department will consider graduate students from three different sources:

(a) graduates of the Lowell Technological Institute B.S. Paper Engineering course;

(b) paper engineering B.S. and M.S. graduates of other schools;

(c) general B.S. and M.S. engineering graduates with no previous paper training.

Students with the backgrounds given under (a) and (b) should be able to complete the work in one academic year. Students in group (c) should be able to complete the degree requirements in two academic years.

A graduate student in Paper Engineering will take approximately 50% of his graduate subjects (including thesis) in the Paper Engineering Department. The balance may be taken as electives related to the paper field and approved by the Department.

The graduate subjects offered in this Department are:

PA 501-502	Graduate Thesis	(1-9) (1-9)8
PA 503-504	Plant Design	(4-0) (4-0)8
PA 505-506	Advanced Papermaking and Paper Converting	(2-6) (2-6)8
PA 507-508	Graduate Seminar	(1-0) (1-0)0

Physics and Mathematics

The graduate program in Physics and Mathematics provides an opportunity for advanced study and the development of research capacity in these combined fields, which have a considerable interplay upon each other. An integrated course of study is worked out with each student, who is encouraged to include work in chemistry or other allied fields. Major emphasis may be given to either physics or mathematics, but if the latter, the student is expected to gain appreciation of the applications of mathematics as well as of its rigor.

The laboratories of the Department of Physics and Mathematics are well set up for investigations in crystal physics and other aspects of solid state physics, with excellent equipment in X-rays, spectroscopy, and electron microscopy. The equipment of the Institute in nuclear physics is rapidly increasing.

Subject Requirements—Of the 20 credit minimum, exclusive of thesis, required in listed courses (see Requirements for Graduation at the end of the Graduate School section), 15 credits must be taken in physics and mathematics. The remaining credits (five or more) may be taken in physics and mathematics or in a related field. A

reasonable and consistent program of study is prepared by the student and his advisory committee consisting of two or more members from the faculty of the Division of Engineering, one of whom is the thesis supervisor. This committee is appointed by the Director of the Graduate School upon the recommendation of the Chairman of the Division of Engineering. Entering students who are found to be deficient in any areas of the undergraduate curriculum in Engineering Physics may be required to take appropriate courses in that curriculum.

Language Requirements—For the degree of Master of Science in Physics and Mathematics the student must demonstrate his ability to read scientific German or Russian.

Thesis Examination—Each candidate for a Master of Science degree in Physics and Mathematics, upon completion of his thesis, shall present himself for an oral examination in the field of his thesis to an examination committee appointed by the Director of the Graduate School and consisting of his advisory committee and any additional faculty members considered desirable by the Director. The examination shall be held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Application to take the examination must be filed by the student with the Director of the Graduate School at least one month prior to the close of the last semester. Each student has a right to one re-examination within a period of one year.

Textile Chemistry

Graduate work in Textile Chemistry allows qualified students the opportunity to pursue advanced study in the physical chemistry of textile processing such as dyeing, wet finishing and fiber modification. Studies in the organic chemistry of dyes may also be undertaken. Recent studies have been on the theories of dyeing of natural and synthetic fibers and the application of synthetic finishes. Such studies are carried out by graduate class work, seminars, and original thesis.

The following subjects must be included in the student's program:

First Semester:

CH 503	Interpretation of Data	(2-0)2
CH 505	Physical Chemistry of Dyeing	(2-3)3
CH 531	Chemical Thermodynamics	(3-0)3
CH 555	Textile Chemistry Seminar	(2-0)2

Second Semester:

CH 512	Physical Chemistry of Surface-active Agents	
or		(2-0)2
CH 538	Rheology	
CH 556	Textile Chemistry Seminar	(2-0)2

Recommended electives include CH 561-562 and CH 563-564.

Textile Engineering

The Master of Science in Textile Engineering degree program has been developed so that qualified students may pursue advanced studies in the field of textiles, with primary emphasis upon the mechanical, engineering, or physical aspects of the field. There is a broad enough selection of subjects and research topics so that those interested in the physical and mechanical properties of fibers and textile structures and methods of evaluating them, as well as those who wish to work at an advanced level on textile design, processing, or manufacturing equipment, will have the opportunity to do so.

Candidates—Candidates should preferably possess a B.S. degree in Textile Engineering, Mechanical Engineering, or Electrical Engineering.

Subject Requirements—The program for each student is arrived at after consultation with the Chairman of the Division of Textiles, with the desires and needs of the student being considered. Of the 20 credit minimum, exclusive of thesis, required in listed subjects (see Requirements for Graduation), at least 10 credits must be taken in the area of textiles, and not more than five credits may be taken in the fields of general studies or chemistry. At least an additional five credits must be taken in the field of engineering. All subjects must be approved by the Chairman of the Division of Textiles.

Thesis Examination—Each candidate for a Master of Science degree in Textile Engineering, upon completion of his thesis, shall take an oral examination in the field of his thesis. This examination shall be conducted by a committee appointed by the Director of the Graduate School and consisting of his thesis supervisor and advisers and any additional faculty members considered desirable by the Director. All faculty members may attend, but only members of the Examination Committee may conduct the examination. The examination shall be held after the thesis has been accepted and within a period of two weeks prior to the close of the semester in which the student expects to be a candidate for the degree. Application to take the examination must be filed by the student with the Director of the Graduate School at least one month prior to the close of the designated semester. If the student fails the oral examination, he has the right to one re-examination within a period of one year. Failure in the re-examination will require the satisfactory completion of a new thesis subject.

MASTER OF SCIENCE DEGREE REQUIREMENTS

Term of Residence

Applicants with a sufficient background in their chosen field of concentration will normally require one academic year of residence to complete the requirements for the master's degree. Those with no background will require a minimum of two years of residence.

Graduates of other colleges usually need more than one academic year to fulfill the degree requirements even though they majored as undergraduates in their graduate field of specialization.

Candidacy for a Master's Degree

Admission to a master's degree program does not indicate that the student is a candidate for the master's degree. A student enrolled in a graduate degree program who has established an acceptable scholarship record and has completed half of the required program may make application to the Director of the Graduate School to become a candidate for the degree.

Application for approval of candidacy for the advanced degree must be filed after completion of one-half of the required program and not later than twelve weeks prior to the date on which the degree is to be conferred.

Requirements for Graduation

To be recommended for the Master of Science degree a candidate must have:

(a) completed a course of study approved by the department in which he has been enrolled. The approved course of study is to have a minimum of 30 credit hours, including thesis. A minimum of 20 credit hours is to be spent in listed subjects, and the program should have no fewer than five credit hours of thesis work.

(b) completed a thesis (orginal research or other investigation, optional with department) approved by the department in which he has been enrolled, and successfully passed any oral or written examinations on his thesis required by the department at the time his thesis is submitted for final approval.

(c) maintained residence for at least one academic year.

(d) maintained an average rating of B in graduate subjects and passed all undergraduate subjects submitted for graduate credit with a grade of B or better.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

Chemistry

The doctoral program in Chemistry is designed to provide both advanced knowledge and research training in chemistry, particularly in the fields of organic, physical, and textile chemistry.

Plan of Program

The doctoral degree will normally require from three to four years of study beyond the bachelor's degree, and a minimum of two to three years beyond the master's degree.

The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his advisory committee or, pending its appointment, with his temporary adviser.

Immediately upon entrance, each student is given a set of three evaluation examinations administered by the Chemistry Division in the fields of organic chemistry, physical chemistry, and combined analytical-inorganic chemistry. The results of these examinations will serve as a guide for the student and advisory committee in planning the program of study.

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. His first year is usually devoted to graduate courses in the major branches of chemistry in preparation for his qualifying (candidacy) examinations. These examinations are taken preferably at or near the end of his third semester. The second year is devoted primarily to advanced courses in a special field of concentration in preparation for the major examinations which are normally taken at the close of his fourth semester of graduate study.

The second and final part of the program is devoted primarily to research leading to the doctoral thesis. However, students are encouraged to begin research as early as possible in their program of study.

Upon entrance to the doctoral program, each student is assigned an advisory committee. This committee is appointed by the Director of the Graduate School, based upon recommendation by the Chairman of the Chemistry Division, and consists of at least three members of the faculty, at least two of whom are from the faculty of the Chemistry Division. One member of the committee representing the student's major field of interest serves as temporary chairman. After the student has selected his thesis supervisor, the

temporary chairman of the advisory committee is replaced by the thesis supervisor, who then serves as permanent chairman.

Course Offerings and Distribution

As a basis for the candidacy examinations, the following core of courses is recommended for first-year students in the doctoral program:

*CH 443-444	Advanced Inorganic Chemistry	(3-0) (3-0)6
CH 513-514	Physicochemical Methods	(2-4) (2-4)6
CH 521-522	Physical Organic Chemistry	(3-0) (3-0)6
CH 531-532	Chemical Thermodynamics	(3-0) (3-0)6

Additional courses may be taken in the minor or in the major field of concentration provided that prerequisites are met.

In the second year, courses supporting concentration in specific fields are available as follows, but selection is not restricted to those subjects listed below in a given field of concentration:

ORGANIC CHEMISTRY

CH 523-524	Organic Chemistry of Polymeric Species	(3-0) (3-0)6
CH 527	Metal-Organic Compounds	(3-0)3
CH 528	Steriochemistry	(3-0)3
CH 529	Heterocyclic Chemistry	(3-0)3

PHYSICAL CHEMISTRY

CH 533	Statistical Mechanics for Chemists	(3-0)3
CH 534	Quantum Mechanics for Chemists	(3-0)3
CH 535-536	Advanced Topics in Physical Chemistry	(3-0) (3-0)6

TEXTILE CHEMISTRY

CH 501	Color Measurement	(1-3)2
CH 505	Physical Chemistry of Dyeing	(2-3)3
CH 512	Physical Chemistry of Surface-active Agents	(2-0)2
CH 538	Rheology	(2-0)2
CH 551 or 552	Textile Testing Problems	(1-3)2
CH 553-554	Evaluation of Finishing Agents	Credits to be arranged
CH 561-562	Polymer Chemical Principles in the Technology of Organic Construction Materials	(3-0) (3-0)6
CH 563-564	Special Topics in the Chemistry and Technology of Manufactured Fibers	(2-0) (2-0)4

Seminar

During each year of residence the student will be required to attend and to participate in graduate seminars. Normally, Chemistry Seminar, CH 507-508, (1-0) (1-0)2, will be taken, but students

*May be taken either for graduate or undergraduate credit.

wishing to specialize in Textile Chemistry may instead elect Textile Chemistry Seminar, CH 555-556, (2-0) (2-0)4, during the first year of study.

Majors and Minors

The prospective candidate is expected to supplement his training in the major field of interest by electing a minor. To avoid overspecialization, this minor must be in a field outside of chemistry. The minor may be divided between two fields if the student so desires. Concentration in the minor field or fields should represent a minimum of nine credits. Subjects in the minor are normally taken during the first two years of study.

DOCTOR OF PHILOSOPHY DEGREE REQUIREMENTS

Term of Residence

Work done only during the regular academic year from September to June can be counted toward residence credit. A minimum of one full academic year of study in residence is required of all candidates. A full year constitutes not less than 36 credit hours of work. Students carrying less than a full-time program must spend a proportionately longer time. Semesters in residence should be consecutive if possible.

All requirements for the doctorate must be completed within seven years after the student's entrance, and within four years after admission to candidacy. Extension of time beyond this limit may be granted only with the joint approval of the student's advisory committee and the Graduate School committee.

Candidacy for the Doctorate

To be admitted to candidacy for the doctorate, a student must have:

(a) completed the first year's core of advanced courses in physical chemistry, organic chemistry, inorganic chemistry, and physicochemical methods and have had a satisfactory record in undergraduate training, graduate seminar, and collateral reading.
(b) filed a written request to take the qualifying examinations.
(c) passed these qualifying examinations which test his general knowledge. One day is devoted to an examination in each of the following areas: organic chemistry, physical chemistry, and combined inorganic-analytical chemistry.
(d) fulfilled the language requirements, as noted below.
(e) secured the approval of his advisory committee and the Division Chairman.

When the above requirements have been fulfilled, the Division Chairman will so notify the Director of the Graduate School in writing and recommend that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy does not in any way guarantee the granting of the degree.

Requirements for Graduation

To be recommended for the Doctor of Philosophy degree, a candidate must have:

(a) satisfied the residence requirements.

(b) pursued an approved program of study that includes the satisfactory completion of at least 90 credit hours beyond the bachelor's degree or equivalent. At least half of these credits will be in formal course work exclusive of seminars or thesis. Graduate credit will be allowed only for grades of C or better in graduate (500) subjects (or certain advanced undergraduate subjects) and B or better in approved undergraduate subjects. An average of B or better must be maintained in graduate subjects which are used for degree credit.

(c) demonstrated satisfactory reading ability in German and one other language (preferably French or Russian). Foreign students may under certain circumstances substitute their native tongue for one of the languages. Both language examinations must be passed prior to advancement to candidacy and before extensive work on the thesis is begun.

(d) passed the qualifying examinations for candidacy.

(e) passed the major examinations in the field of concentration. These examinations are devoted primarily to the testing of the student's knowledge in his special field of concentration and will draw heavily on knowledge gained during his second full year of study in this particular area. They are given only when substantially all of the formal course work has been completed, normally at the end of the second full year (fourth semester). The major examination is in two parts. The first part will be written and will extend over a period of one day. It will test the student's broad knowledge in his specific field of concentration. The second part of the major examination will be oral and will test the student's aptitude for research and his ability to organize and to develop a research problem. The examination will take the form of the defense of a proposition. The student will select a problem with the approval of his advisory committee.

(f) completed a satisfactory thesis. The doctoral thesis is designed to permit the student to demonstrate his ability to conduct original and independent research work. The results of the thesis investigation should constitute a definite contribution to knowledge in the field of specialization and should be suitable for publication. The field of the thesis investigation should be selected as soon as possible after admission to the graduate program, and the subject of the thesis must be approved by the advisory committee. As soon as the subject has been selected, the student must

make his choice known to the Department Head, who in turn will notify the Graduate School so that the list of theses in progress may be kept current. The thesis subject must be filed not later than two weeks after the student has been admitted to candidacy. While the nature of the results of the thesis investigation provides the basic criterion for determining the time required for the thesis, thesis credit will normally constitute about half of the total credit requirement. As a rule, from three to four semesters of full-time work will be required.

(g) passed a thesis examination. This is an oral defense of the student's thesis before the faculty of the Department of Chemistry and Textile Chemistry.

(h) satisfied all requirements as to tuition and fees.

OFFICIAL ROSTER OF GRADUATES

DEGREES CONFERRED IN 1957

Bachelor of Science

Ruben L. Abadi
Yervant Edward Annaian
John George Arslanian
Joseph Bellemore
Arthur Joseph Berkowitz
Gerald Edwin Boches
Martin Lewis Bristow
Philip Bradford Burgess
Carlos Antonio Ceppas
George Arthur Cherry
Chris Chingros
Hyman Kenneth Cohen
Leonard T. Coppeta
Nicholas Dadoly
Edward Joseph Delaney
Ernest Elias Deveres
‡Paul Daniel Donovan
Robert Huntington Durkee
Richard Brom Engel
John Cushier Ferenbach, Jr.
‡John Timothy Finnegan
‡Ronald Alfred Francoeur
Carmen Frank Genzabella
Theodore Charles Giras
Warren Edward Goddard
Roman Golbin
Louis Stewart Goldberg
Allan Ainley Gwinnell
Gerald Floyd Harlam
Richard Arthur Heiden
Chris Kapetanakis
Robert Herman Keenan
William Bryant Kennerly, Jr.
Thomas Michael Keville, Jr.
Chawl Whan Kim
William Robert King
‡**Vincent William Kulickowski, Jr.
Joseph William Lahood
Donald Earl Levin
Jacob T. Litt
Frederick Ryeburn Lynch
William Patrick Mahoney
Frank William Major
‡**Frank Vernon Mann
Leonard Jay Miller
Lewis H. Miller
Plymouth Dixon Nelson
Edward Novick
John Joseph O'Keefe
Abraham O. M. Okorodudu
‡Rino Louis Pellissier
Jack Austin Perry
Therese Ann Polak
James Edward Powers
John Thomas Roddy
‡Roger Edgar Rondeau
Cornelio B. Sarangaya
Richard Cole Savage
Richard Earl Sawyer
John Herbert Scaringi
Robert Carl Schiek
Richard Arnold Silver
William Spielman
Bernard Joel Stein
Philip Curtis Swain
Miguel Teubal
Harry Norman Tobler
Adolphe Arthur Traversy
Jo Van der Linden

‡Commissioned Second Lieutenent in the United States Air Force Reserve
**Distinguished AFROTC graduates

Ricardo Villa Escalera
William Rogers Walsh, Jr.
Robert P. L. Yung
Walter C. S. Yung
Maurice George Vacherot
Charles Zaharias
Howard M. Zins

Bachelor of Science with Honors

*Raynal Emile Desrochers
*David Malcolm Hannon
Leo Augustine Hart
*Yashvant Chandulal Jariwala
Leonard Lifland
*Edward Lee McGann
Richard Thomas Meserve, Sr.
‡Peter Gerald Popper
David Laurence Porter

Bachelor of Science with High Honors

*Frances Stephanie Delaney

Master of Science

Robert Chun-Ti Ang — *Textile Engineering*
B.E.E., Manhattan College, 1955

Peter Clement Canovai — *Textile Chemistry*
B.S., Lowell Technological Institute, 1955

*Allen Albert Denio — *Textile Chemistry*
B.S., Lowell Technological Institute, 1956

Edward Walter Makuch — *Textile Chemistry*
B.S., Bradford Durfee Technical Institute, 1953

HONORARY DEGREES

Doctor of Science

His Excellency Foster Furcolo
Governor of the Commonwealth

Paul F. Clark
Chairman of the Board
John Hancock Mutual Life Insurance Company

Herbert James Ball
Professor Emeritus, Lowell Technological Institute

*Tau Epsilon Sigma (Lowell Technological Institute Scholastic Honor Society)
‡Commissioned Second Lieutenant in the United States Air Force Reserve

OFFICIAL ROSTER OF GRADUATES

DEGREES CONFERRED IN 1958

Bachelor of Science

William Eugene Archambault
Charles R. Baker
James Philip Bath
*Thomas Joseph Bennett
Philip Donald Bixby
Donald Branchaud
Alden Reynold Bratt
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A SIMPLIFIED TREATMENT OF RIGID DYNAMICS

I. A Visualization of the Physical Significance of the Products of Inertia

II. An Elementary Proof of the Existence and Mutual Perpendicularity of the Principal Axes.

L. IVAN EPSTEIN*

INTRODUCTION

In the elementary treatment of rigid dynamics as it is commonly taught to college freshmen, it is customary to include a few words of explanation concerning the physical significance of moments of inertia. In a more advanced course, where the products of inertia are introduced, students frequently inquire concerning the physical significance of these new coefficients. This question is not easy to answer, since the products of inertia have no physical significance by themselves but only in combination with the moments of inertia. Part I is an attempt to explain by visualization the physical significance of the products of inertia. The existence and mutual perpendicularity of principal axes of inertia through any point of a rigid body are commonly proved with the aid of matrix algebra, tensor analysis, or the theory of surfaces. The proof given in Part II requires only elementary mathematics.

I. A VISUALIZATION OF THE PHYSICAL SIGNIFICANCE OF THE PRODUCTS OF INERTIA

In the particular case where all three products of inertia vanish, the coordinate axes are called the principal axes of the body. We shall leave aside for the moment the question whether an arbitrary rigid body possesses principal axes. For the present, it is sufficient that we can conceive of bodies which do possess principal axes. Some examples will be given in this section. We start out with the basic equations of rigid dynamics

$$
\begin{aligned}
H_x &= I_{xx}\omega_x + I_{xy}\omega_y + I_{xz}\omega_z \\
H_y &= I_{xy}\omega_x + I_{yy}\omega_y + I_{yz}\omega_z \\
H_z &= I_{xz}\omega_x + I_{yz}\omega_y + I_{zz}\omega_z,
\end{aligned}
\tag{1}
$$

where H_x, H_y, H_z are the x, y, and z components of the angular momentum vector $\mathbf{H}$, where ω_x, ω_y, ω_z are the components of the angular velocity vector $\boldsymbol{\omega}$, where I_{xx}, I_{yy}, I_{zz} are the moments of inertia, and I_{xy}, I_{xz}, I_{yz} are the products of inertia. From these equations, it will be seen that a body rotating about a principal axis has $\mathbf{H}$ parallel to $\boldsymbol{\omega}$. For instance, when $\omega_y = \omega_z = 0$, the condition $I_{xy} = I_{xz} = I_{yz} = 0$ gives $H_y = H_z = 0$, so that only ω_x and H_x are nonzero. A similar reasoning holds when $\boldsymbol{\omega}$ falls along the y or z axis. We shall define a principal axis to be an axis of rotation such that $\boldsymbol{\omega}$ and $\mathbf{H}$ are parallel. A body not acted on by any torque and rotating about an axis which is not a principal axis will not have $\mathbf{H}$ constant, so that, by Eqs. (1), $\boldsymbol{\omega}$ will not be constant, whence the motion of such a body will be wobbly.

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I used to know an electrician. He was an intelligent man, but he had never been to college. One day a customer brought him an electric fan which "walked". When running, the fan would vibrate almost imperceptibly, with the result that it gradually moved across the table until it came to the edge and fell off. The electrician gave this explanation for the walking (Fig. 1):

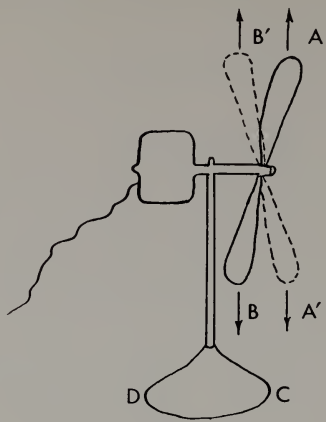

FIGURE 1.

The propeller blades were so bent that the axis of symmetry of the fan did not coincide with the axis of rotation.* As the blades rotated (so the electrician thought) the centrifugal forces would act on the blades in the direction indicated by the arrows. This explanation will, of course, appear crude to the educated, since the centrifugal "force" is not an external force acting on the propeller blades. However, for the sake of the explanation, we shall bear with the electrician.

When the blades are in the position shown solid in the figure, the torque due to the centrifugal forces will be counterclockwise and will rotate the fan and its stand in such a manner that the point C is lifted off the table. Presently, the blade A moves forward, out of the plane of the paper, and this causes the right side of the fan to swing forward in such a manner that C moves out of the plane of the paper before settling down on the table again. Half a turn carries blade A to the dotted position A', and B to B'. Now the torque due to the centrifugal forces is clockwise, with the result that D is lifted off the table and swung forward before it settles down again. The successive lifting caused the points C and D to execute a motion not unlike that of the feet of a walking man. The electrician corrected this condition by bending the blades back into alignment. A more sophisticated explanation would be that the walking fan was not spinning about a principal axis, with the result that it wobbled.

How can anyone teach rigid dynamics to freshmen without telling them about the products of inertia? It is by considering only those cases where the body spins about a principal axis. One important example is the gyroscope, which is a solid of revolution spinning about its axis of revolution. Let this be the z axis. For the validity of the following proof, it is only necessary that the xz plane and the yz plane should be planes of symmetry, which is

*Since this was written, it has come to the author's attention that a somewhat similar explanation is given in J. C. Slater and N. Frank: *Mechanics* (McGraw-Hill Book Company, Inc. 1947). However, it is believed that the present treatment is sufficiently different and that this bulletin contains enough other subject matter of interest to warrant publication.

certainly true of our gyroscope. We shall only prove that $I_{xy} = 0$. The proofs that I_{xz} and I_{yz} vanish are very similar. From the definition of the products of inertia

$$I_{xy} = -\iiint \rho xy\,dx\,dy\,dz \tag{2}$$

where ρ is the density of the body, and the integration extends over the volume of the body. Now if the point (x, y, z) is in the body, so is the point $(-x, y, z)$ and vice versa, and the density ρ is the same at both points. This follows from the fact that the yz plane is a plane of symmetry. Thus, the elements of volume of the body can be grouped together in pairs which make contributions of equal absolute value and opposite sign to the integral in Eq. (2). Hence the integral vanishes. The proof that $I_{xz} = 0$ is almost exactly the same. The proof that $I_{yz} = 0$ is similar, except for the fact that we now make use of the symmetry of the body with respect to the xz plane. These conclusions are always valid, no matter where along the z axis the pivot point (the origin of coordinates) is located.

Another example taught to freshmen is the case of the thin lamina pivoted at a point in its own plane and rotating about an axis normal to its plane. Let this axis be the z axis, so that the entire lamina lies in the xy plane. Then $z = 0$ for every point of the lamina, and from the definition of the products of inertia we have

$$I_{xz} = -\iiint \rho xz\,dx\,dy\,dz = 0 \tag{3}$$

$$I_{yz} = -\iiint \rho yz\,dx\,dy\,dz = 0 \tag{4}$$

Then, if $\omega_x = \omega_y = 0$, it follows from Eqs. (1) that $H_x = H_y = 0$, no matter whether or not $I_{xy} = 0$. Hence the z axis is a principal axis.

As a final example, consider the case of a thin lamina lying in the plane z = constant $\neq 0$, rotating about the z axis, and having its center of mass on the z axis. Similarly as in Eq. (3) we have

$$I_{xz} = -z\iiint \rho x\,dx\,dy\,dz \tag{5}$$

Now, if $\bar{x}$ is the x coordinate of the center of mass, we have

$$\iiint \rho x\,dx\,dy\,dz = M\bar{x} \tag{6}$$

where M is the mass of the body; and since the center of mass is on the z axis, we have $\bar{x} = 0$, whence $I_{xz} = 0$. The proof that $I_{yz} = 0$ is almost identical. Hence the z axis is a principal axis. The value of I_{xy} is immaterial, as explained in the preceding example.

If the z coordinate of the lamina is not zero and the center of mass is not on the z axis, the z axis will not be a principal axis. This requires a word of explanation (Fig. 2). If the lamina lies in the xy plane, the z axis will be a principal axis even though the center of mass does not lie on the z axis. Now let the coordinate axes be translated in such a manner that the origin moves along the z axis. After this transformation, the z axis is no longer a principal axis even though its position has not changed. Why?

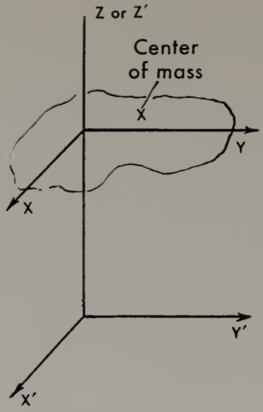

FIGURE 2.—The z axis is a principal axis, the z' axis is not.

We developed the theory subject to the hypothesis that the origin of coordinates is either at the center of mass or at a fixed pivot point. In this instance, the origin is not at the center of mass. Now, in general, the support will exert a force on the body at the pivot point. In the absence of such a force, the center of mass and not the pivot point would be fixed or moving at a constant velocity. If there are no other forces acting on the body, there will be no torque about the origin. Let us describe the motion from the electrician's point of view. First, let the pivot point be in the plane of the lamina but not at the center of mass. Let the lamina be spun about an axis normal to its plane and passing through the pivot point, and let it be subject to no applied forces other than that which holds the pivot point at rest. A "centrifugal force" tends to pull the center of mass away from the pivot point. But this force passes through the pivot point, exerts no torque about it, and therefore does not affect the motion.

In the second case, let a thin massless rod be rigidly attached to the lamina at right angles to its plane and so that it coincides with the z axis of the preceding example (Fig. 3). Let the end of this rod be the new origin and

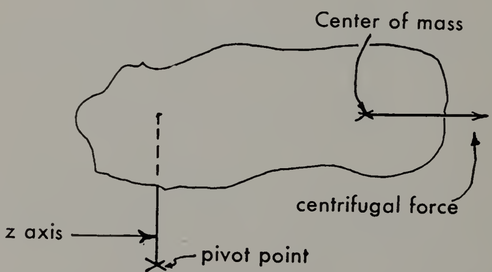

FIGURE 3.

pivot point, and again, let the angular velocity vector coincide initially with this z axis. The electrician would say that the centrifugal force on the center of mass no longer passes through the pivot point. It therefore exerts a torque about the origin, and the result is a wobbly motion.

II. AN ELEMENTARY PROOF OF THE EXISTENCE AND MUTUAL PERPENDICULARITY OF THE PRINCIPAL AXES

As pointed out in the preceding section, $I_{xz} = I_{yz} = 0$ is a sufficient condition to make the z axis a principal axis, even when the x and y axes are not principal axes. In this case, if $\omega_x = \omega_y = 0$, it follows from the last of Eqs. (1) that $H_z = I_{zz}\omega_z$. That is to say, if a rigid body rotates about a principal axis, the angular momentum vector equals the product of the angular velocity vector by the (scalar) moment of inertia about that axis.

Now consider the general case where the products of inertia are not all zero. We shall prove that there exist three mutually perpendicular principal axes through the same origin as the given axes. Let I be the moment of inertia about one of those principal axes. Then, if the vector $\boldsymbol{\omega}$ lies along that principal axis, we have $\mathbf{H} = I\boldsymbol{\omega}$. Substituting for the components of $\mathbf{H}$ in Eqs. (1), we obtain

$$\begin{aligned} I\omega_x &= I_{xx}\omega_x + I_{xy}\omega_y + I_{xz}\omega_z \\ I\omega_y &= I_{xy}\omega_x + I_{yy}\omega_y + I_{yz}\omega_z \\ I\omega_z &= I_{xz}\omega_x + I_{yz}\omega_y + I_{zz}\omega_z \end{aligned} \tag{7}$$

Rearranging slightly, we obtain

$$\begin{aligned} (I_{xx} - I)\omega_x + I_{xy}\omega_y + I_{xz}\omega_z &= 0 \\ I_{xy}\omega_x + (I_{yy} - I)\omega_y + I_{yz}\omega_z &= 0 \\ I_{xz}\omega_x + I_{yz}\omega_y + (I_{zz} - I)\omega_z &= 0 \end{aligned} \tag{8}$$

When all the I's are known (including the one without subscripts), we can solve Eqs. (8) for the ω's. In general (namely, if the value of I chosen does not correspond to any principal axis) the solution is $\omega_x = \omega_y = \omega_z = 0$. If non-zero values of the ω's are to be possible, the three Eqs. (8) must be compatible. A necessary condition for this is that the determinant of the coefficients in Eqs. (8) must vanish, that is,

$$\begin{vmatrix} I_{xx} - I & I_{xy} & I_{xz} \\ I_{xy} & I_{yy} - I & I_{yz} \\ I_{xz} & I_{yz} & I_{zz} - I \end{vmatrix} = 0$$

When the determinant is expanded, this equation takes the form

$$-I^3 + AI^2 + BI + C = 0 \tag{9}$$

where A, B, C are functions of the I's with subscripts. The cubic polynomial which is here equated to zero is a continuous function of I. When I is very large (positive), the term cubic in I outweighs all the other terms in absolute value, and the polynomial is strongly negative. Similarly, if I is negative and large in absolute value, the polynomial is positive. It follows that Eq. (9) must be satisfied by at least one real value of I, so that the body must possess at least one principal axis. Since Eq. (9) is cubic in I, it may possess as many as three real roots. We shall show that this will always be the case.

Having obtained the moment of inertia I about one of the principal axes, we substitute its value into Eqs. (8). These equations are now compatible, so that only two of them are needed. Choosing ω_x arbitrarily, we may solve two of Eqs. (8) for ω_y and ω_z. Writing

$$|\omega| = \sqrt{\omega_x^2 + \omega_y^2 + \omega_z^2} \tag{10}$$

we obtain the direction cosines of the principal axis corresponding to the value of I obtained:

$$\frac{\omega_x}{|\omega|}, \quad \frac{\omega_y}{|\omega|}, \quad \frac{\omega_z}{|\omega|} \tag{11}$$

Now let us rotate the coordinate axes, keeping the origin fixed, so that the one principal axis obtained so far becomes the new z axis. The transformation equations need not concern us here. It suffices that we can conceive of such a transformation in geometrical terms. We shall distinguish all quantities referred to these new axes by primes. We now have

$$I'_{xz} = I'_{yz} = 0 \tag{12}$$

Let us search for possible principal axes in the $x'y'$ plane. We now have a set of equations analogous to Eqs. (8) but with a prime affixed to all symbols except I. If $\boldsymbol{\omega}$ lies in the $x'y'$ plane, we have $\omega'_z = 0$. Keeping Eqs. (12) in mind, we obtain in place of Eqs. (8)

$$\begin{aligned} (I'_{xx} - I)\omega'_x + I'_{xy}\omega'_y &= 0 \\ I'_{xy}\omega'_x + (I'_{yy} - I)\omega'_y &= 0 \end{aligned} \tag{13}$$

The third of Eqs. (8) degenerates to the form $0 = 0$. By the same reasoning as before, Eqs. (13) can be satisfied by non-zero values of ω'_x and ω'_y only if

$$\begin{vmatrix} I'_{xx} - I & I'_{xy} \\ I'_{xy} & I'_{yy} - I \end{vmatrix} = 0 \tag{14}$$

Expanding the determinant, we obtain

$$I^2 - (I'_{xx} + I'_{yy})I + I'_{xx}I'_{yy} - I'^2_{xy} = 0 \tag{15}$$

The solutions of Eq. (15) are

$$I = \frac{I'_{xx} + I'_{yy} \pm \sqrt{(I'_{xx} + I'_{yy})^2 - 4I'_{xx}I'_{yy} + 4I'^2_{xy}}}{2} =$$

$$\frac{I'_{xx} + I'_{yy} \pm \sqrt{(I'_{yy} - I'_{xx})^2 + 4I'^2_{xy}}}{2} \tag{16}$$

Since the quantity under the square root sign is the sum of two squares, it is positive, so that the two solutions of Eq. (15) are always real.

If the vector $\boldsymbol{\omega}'$ lies in the $x'y'$ plane, its slope S with respect to the x' axis is given by $S = \frac{\omega'_y}{\omega'_x}$. From the first of Eqs. (13), this is found to be

$$S = \frac{\omega'_y}{\omega'_x} = \frac{I - I'_{xx}}{I'_{xy}} \tag{17}$$

Substituting for I from Eq. (16) into Eq. (17), we obtain two possible values for the slope of a principal axis in the $x'y'$ plane

$$S = \frac{I'_{yy} - I'_{xx} \pm \sqrt{(I'_{yy} - I'_{xx})^2 + 4I'^2_{xy}}}{2I'_{xy}} \tag{18}$$

We shall show that these two principal axes are mutually perpendicular. If this is to be the case, the product of their slopes must be -1. Indeed, the product of the two values of S from (18) is

$$\frac{(I'_{yy} - I'_{xx}) + \sqrt{(I'_{yy} - I'_{xx})^2 + 4I'^2_{xy}}}{2I'_{xy}} \times$$

$$\frac{(I'_{yy} - I'_{xx}) - \sqrt{(I'_{yy} - I'_{xx})^2 + 4I'^2_{xy}}}{2I'_{xy}} =$$

$$\frac{(I'_{yy} - I'_{xx})^2 - (I'_{yy} - I'_{xx})^2 - 4I'^2_{xy}}{4I'^2_{xy}} = -\frac{4I'^2_{xy}}{4I'^2_{xy}} = -1 \tag{19}$$

which was to be proved.

To sum up, we have shown that there are at most three principal axes and that there is at least one. We chose one to be the z' axis. In connection with Eq. (16), we showed that there are two more in the $x'y'$ plane, and these, of course, are perpendicular to the first. Finally, from Eq. (19), it follows that the two principal axes in the $x'y'$ plane are mutually perpendicular. It follows that any rigid body always possesses three mutually perpendicular principal axes through any one of its points.